ELECTRODE SYSTEM FOR PRODUCTION OF A HOMOGENEOUS ELECTRIC FIELD WITHIN A VOLUME BOUNDED BY CONDUCTIVE WALLS

A. V. Bolotov, A. V. Kozyrev, Yu. D. Korolev,
and L. I. Luchinskaya

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In the study of gas and vacuum discharges and construction of various electrophysical equipment, it becomes necessary to produce a homogeneous electric field with a system of two electrodes. Both axisymmetric electrodes and ones with linear size in one dimension significantly exceeding that in the other two have been used. The problem of selecting the proper profile has been solved successfully for the case of free space [1] (Rogovsky, Chang, and other profiles). Placement of the electrode system within a metallic shell significantly distorts the electric field distribution. Numerical calculations of the field with consideration of the metallic walls of the discharge chamber for some model situation were presented in [2]. However, the results presented there, referring to the axisymmetric case, do not provide practical guides to selection of electrode profiles and minimization of discharge chamber dimensions. The present study proposes a configuration for the discharge chamber—electrode system which insures deviations of the electrode potential from its maximum value limited to several percent. Recommendations are offered for simulation of various electrode configurations with a BÉSM-6 computer using the KSI-BÉSM compiler system [3]. The results presented are for a plane two-dimensional model, i.e., constructions where the longitudinal dimension of the electrode is significantly greater than the transverse.

The typical construction used for excitation of gas discharges includes a potential electrode located within a metallic chamber and a ground electrode connected to the chamber wall. The problem consists of producing homogeneity of the field in the working region of the interelectrode gap and insuring that the chamber wall is far enough removed to eliminate breakdown between the side surface of the electrode and the wall. It is clear that the profile of the internal potential electrode must be described by a smooth curve with sufficiently large radii of curvature.

For computer optimization of the electrode system it is necessary to somehow limit the class of parameters to be varied. Therefore, we propose an internal electrode profile in the form of a Cassini oval [4] (Fig. 1, curve 1). This is the geometric locus of points having the following property: the product of the lengths of the segments F_1M and F_2M is equal to the constant a^2, with the distance between the points F_1 and F_2, called the foci, being equal to 2c. Here a and c are the parameters of the curve. The equation of the oval is

$$y^2 = (4c^2x^2 + a^4)^{1/2} - x^2 - c^2. \tag{1}$$

Further, for convenience we will take c = 1, so that the length of the oval's minor semiaxis will be $(a^2 - 1)^{1/2}$ and the major semiaxis will be $(a^2 + 1)^{1/2}$. For $a \gg c$ we obtain a curve close to a circle.

We will now consider a system of two confocal ovals (curves 1 and 2 of Fig. 1), differing in their parameters a. The inner surface has a potential U, while the outer is grounded. Then the field intensity on the surface of curve 1 will be described by the expression

$$E_1 = 2U(x^2 + y^2)^{1/2}/[a_1^2 \ln(a_2^2/a_1^2)], \tag{2}$$

where a_1 and a_2 are parameters of curves 1 and 2. It is evident from Eq. (2) that the intensity reaches a maximum E_m at the point A and depends logarithmically on parameter a_2. If we specify the quantity a_1 and the value of E_0 such that $E_m \le E_0$, then Eq. (2) may be used to define the parameter a_2 and, thus, the size of the external wall:

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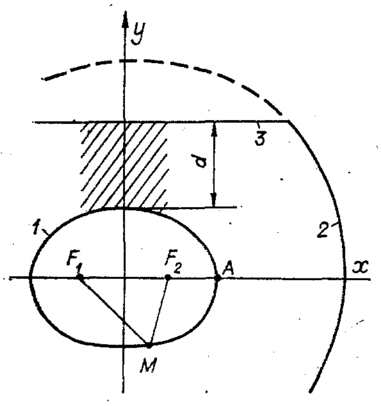

Fig. 1

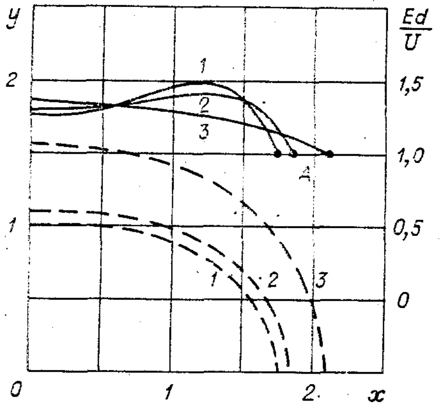

Fig. 2

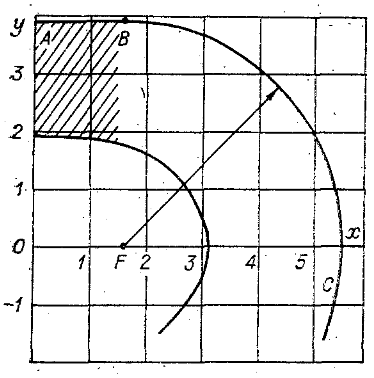

Fig. 3

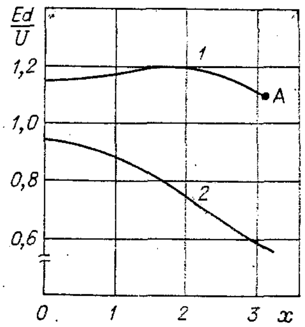

Fig. 4

$$a_2 = a_1 \exp\left[U\left(a_1^2 + 1\right)^{1/2}/E_0 a_1^2\right]. \tag{3}$$

Equation (3) was used for preliminary estimates in optimizing electrode systems. The potential electrode was taken in the form of a Cassini oval, while the second grounded electrode was made planar (line 3 of Fig. 1). The interelectrode distance d = 2c is such that the homogeneous field region is close to square in form (shaded in Fig. 1).

The value of a_1 was chosen, Eq. (3) was used to determine a_2, with $E_0 = U/d = U/2$. Results of a numerical calculation of the field on the surface of the internal electrode are shown in Fig. 2, where the dashed curves represent electrode profiles and the solid curves the corresponding field intensities. If the electrode is greatly elongated (curve 1, $a_1^2 = 2$), then at the edge of the working region there is a significant increase in field, while with increase in a_1 the inhomogeneity decreases (curve 2, $a_1^2 = 2.3$), and at $a_1^2 = 3.4$ (curve 3) the field is close to homogeneous. We note that at point A the intensity is always lower than in the working zone. This permits moving the side wall (curve 2 of Fig. 1) closer to the external electrode, decreasing the size of the system. As a result of such optimization a system was obtained which is simple to construct in practice (Fig. 3). The internal electrode is a Cassini oval with parameters c = 1.7, $a = 2.58$. Its form is specified by Eq. (1). The grounded wall consists of a planar segment AB with half-width c = 1.7 and an arc of a circle BC with radius R = 3.94 and center at the oval focus F. The electric-field distribution on the electrode surfaces is shown in Fig. 4 (curve 1, internal potential electrode; curve 2, outer grounded electrode). We note that the field on the outer electrode is markedly higher than on the wall, and field variations do not exceed 5%.

We have considered here the case of an electrode system extended in the z direction, which permitted limiting the field calculations to the xy plane. However, in designing a concrete discharge chamber, it is necessary to select the lateral shape of the electrode. Of the possible variants, the most simple and smoothest is the surface formed by rotation of the oval about its minor axis. Field intensification at the ends can be compensated by removal of the end walls to a distance of ~2d from the internal electrode.

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MEASUREMENT OF THE TEMPERATURE OF GAS BETWEEN THE BUSBARS OF A FLAT MAGNETOCUMULATIVE GENERATOR

V. P. Isakov and A. S. Nuzhdov

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The study of air flow between metallic plates colliding with a high velocity (of the order of several kilometers per second) is of great interest in connection with problems arising in the study of processes occurring in magnetic-explosion generators, explosion plasma compressors [1], and in explosion welding [2]. As a result of the collision of the plates, a region of shock-compressed gas (gas plug), which grows in size as the distance from the beginning of the collision increases, is created in front of the moving point of contact. The heated gas should have an especially strong effect on the operation of cylindrical magnetic-explosion generators, since in these generators there is no lateral surface through which gas can flow out.

The gas temperature was measured by the brightness method according to the relative blackening of the photographic film when the source and a standard were photographed simultaneously with a high-speed camera [3, 4]. The standard was a shockwave (SW), excited in a cylindrical channel by detonating an explosive charge, the constancy of whose velocity and brightness temperature was proved in [5].

In the experiments, whose arrangement is shown in Fig. 1, the detonator 1, which detonated the intermediate charge 2, excites a detonation wave in a gas-shaped charge 3, and the plasmoid formed is pushed out into the cylindrical tube 4. The plasmoid moving past the slits 5 is photographed; at the same time, the mirror 6 projects the image of the shockwave from the end of the tube through the window 7 of the explosion chamber 8 and the stepped attenuator 9 onto the film of camera 10. Then the emission of the gas plug, compressed by the colliding plates, is photographed in the next frame of the film. The arrangement of the experiments on photographing the collision of steel or duraluminum plates, arranged in parallel, is shown in Fig. 2, where the plate 1 with a cross section of 100 × 2.8 mm was hurled with a 10-mm-thick layer of hexagen 2 into the 80 × 10 mm plate 3. Before the collision the plates were parallel to one another with the gaps between them. The emission from the shock-compressed gas 4 was photographed through diaphragm 6 and interference filter 7 ($\lambda = 450 \pm 2.5$ nm) with camera 8. In some experiments, a multistepped attenuator was used instead of a light filter. In addition (in order to determine the stationariness of the process) the velocity of the point of contact was measured from the difference in the closure of the contacts of the sensors 5 (forming the triggering and stopping signals for the Ch3-33A frequency meter) through a standard triggering circuit. The temperature was determined from the photographs obtained as follows. The velocity of the SW in the cylindrical tube was found from the known distance between the slits and the frame speed, while the temperature was determined from the shock adiabat of air [6]. Knowing the temperature of the standard and the characteristic curve of the film, the temperature of the source can be determined from the degree of blackening of the film.

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