

Nov. 17, 1942.

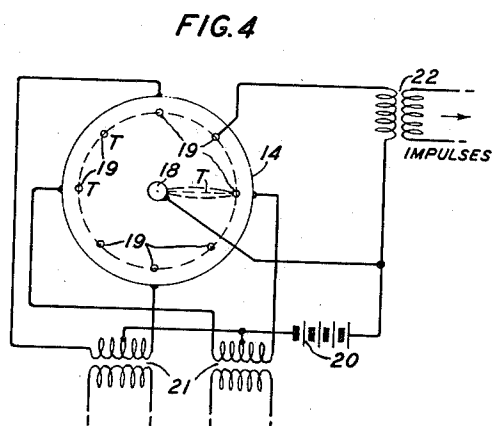
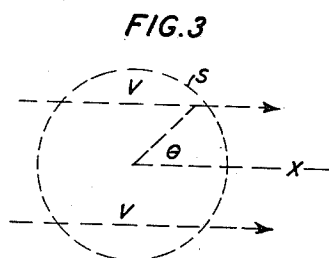
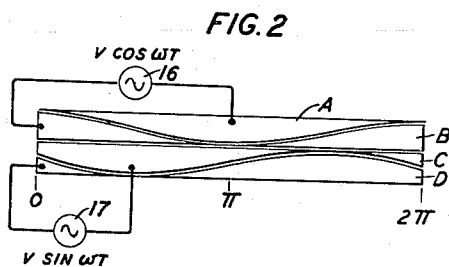
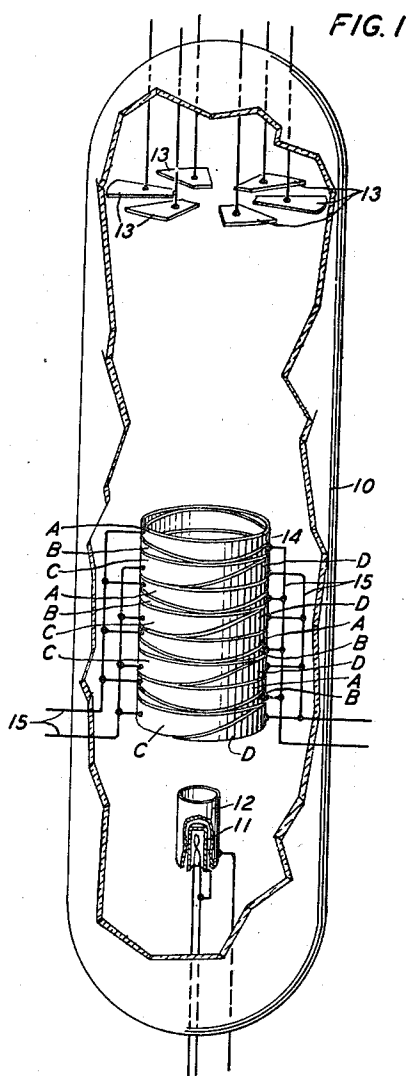
F. GRAY

2,302,118

ELECTRON DISCHARGE DEVICE

Filed Oct. 29, 1941

2 Sheets-Sheet 1



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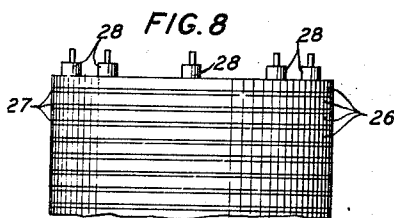
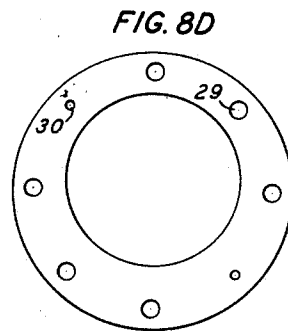
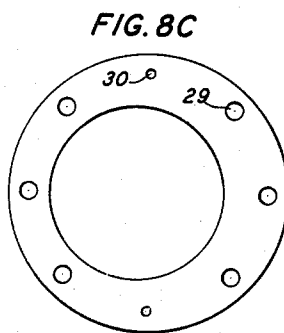
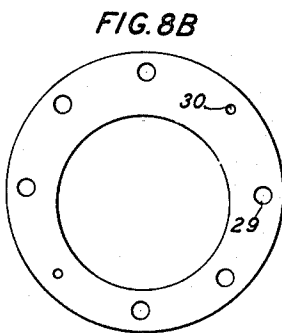
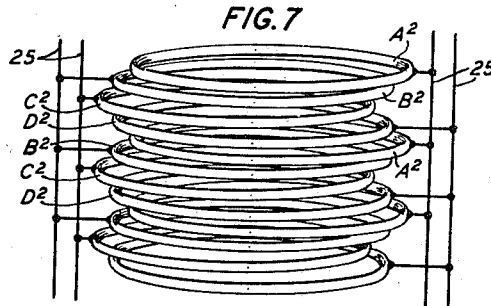
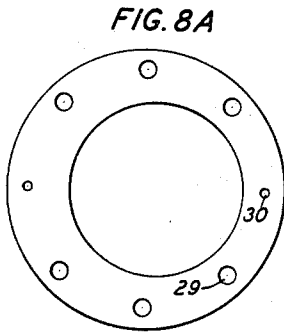
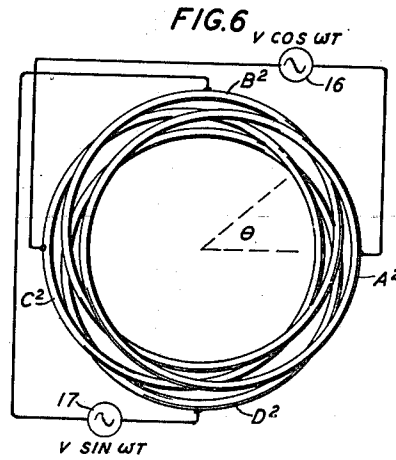
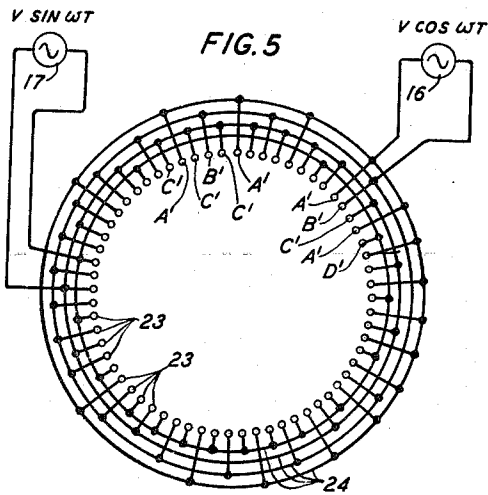
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ELECTRON DISCHARGE DEVICE

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2 Sheets-Sheet 2



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2,302,118

ELECTRON DISCHARGE DEVICE

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Application October 29, 1941, Serial No. 416,926

10 Claims. (Cl. 250—157)

This invention relates to electron discharge devices and more particularly to electrode systems for such devices of the electron beam or cathode-ray type, for controlling the direction of projection of the electron stream.

One object of this invention is to enable the production, in an electron discharge device, of a uniform rotating electric field. More specifically, one object of this invention is to facilitate the rotation of an electron beam about a desired axis and at a desired angular velocity, whereby the beam may be caused to impinge sequentially upon a plurality of target electrodes.

In one illustrative embodiment of this invention, an electron discharge device comprises a source, such as an electron gun, for producing a concentrated electron stream, a plurality of target electrodes toward which the beam is projected, the target electrodes being mounted in circular array, and an electrode system for rotating the electron beam about an axis to cause the beam to impinge upon the target electrodes in sequence.

In accordance with one feature of this invention, the electrode system comprises a cylindrical, unitary, composite or mosaic electrode composed of a plurality of interleaved electrode elements electrically grouped and so constructed and arranged that upon the establishment of a cyclically varying potential difference between the several groups of electrode elements the resultant field is radial with respect to the longitudinal axis of the mosaic electrode and rotates at uniform velocity about this axis, this field being of substantially constant magnitude or intensity.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings in which:

Fig. 1 is an elevational view in perspective of an electron discharge device illustrative of one embodiment of this invention, a portion of the enclosing vessel being broken away to show the electrodes more clearly.

Fig. 2 is a detail view illustrating a development of a portion of the composite or mosaic electrode included in the device shown in Fig. 1 and illustrating also the electrical association of the electrode elements with energizing sources;

Fig. 3 is a diagram which will be referred to hereinafter in the analysis of the operation of the composite or mosaic electrode included in the device shown in Fig. 1;

Fig. 4 is a view, partly diagrammatic and partly

schematic, illustrating another embodiment of this invention wherein the composite or mosaic electrode encompasses the cathode and the beam is in the form of a plane sheet, extending radially from the cathode and rotatable about the cathode;

Figs. 5 and 6 are views similar to Fig. 4 illustrating other embodiments of this invention;

Fig. 7 is a detail perspective view of a composite or mosaic electrode of the type illustrated in Fig. 6;

Fig. 8 is a fragmentary elevational view of a modification of the composite or mosaic electrode shown in Fig. 7; and

Figs. 8A to 8D are detail plan views of the electrode elements included in the composite or mosaic electrode shown in Fig. 8.

Referring now to the drawings, the electron discharge device illustrated in Fig. 1 comprises an evacuated enclosing vessel 10, an electron gun including a cathode 11, for example of the indirectly heated type, and an accelerating electrode 12, adjacent one end of the vessel 10, and a plurality of sectoral target electrodes or anodes 13 adjacent to the other end of the vessel and mounted in equally spaced circular relation about a center coaxial with the electron gun. Mounted between the electron gun and the target electrodes or anodes is a cylindrical composite or mosaic electrode 14 coaxial with the electron gun and effective when energized to rotate the electron stream produced by the gun about the axis of the electrode, whereby the stream is caused to impinge upon the target electrodes or anodes in sequence.

The composite or mosaic electrode 14 comprises a plurality of sets of annular electrode elements mounted in closely adjacent edge-to-edge relation, each element varying in width in a manner described hereinafter. Each set is composed of four electrode elements, designated by the letters A, B, C, and D, and corresponding elements in the several sets are identical and connected together electrically by conductors 15.

It can be shown that the potential at any point within the region bounded by the composite or mosaic electrode is a function of the potential of the several electrode elements and, more specifically, that the potential at any point within the region bounded by any set of elements is the resultant of the potentials of the several elements combined according to areas of the elements.

In general, within a three-dimensional region

of space enclosed by a surface, the electrical potential obeys the Laplacian equation

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = 0 \quad (1)$$

where ϕ is the potential and x , y and z are the rectangular coordinates. Hence, the potential distribution throughout such a region is determined uniquely by the distribution of potential over the bounding surface. Conversely, any desired potential distribution in such a region can be realized by establishing on the bounding surface a potential distribution corresponding to that desired within the region.

In the case of a cylindrical space bounded by a circular cylindrical surface, such as S in Fig. 3, consider an electric field, indicated by the arrows V, parallel to an axis X. The potential at any point on the surface S is, then, given by the relation

$$\phi = V \cos \theta \quad (2)$$

where ϕ is the potential, V is the maximum potential on the surface, and θ is the angle measured from the X axis. If the field is rotated, at a uniform rate of 2π times a frequency, ω , the potential on the surface S is given by the relation

$$\phi = V \cos (\theta - \omega t) \quad (3)$$

where t is time. Hence, a rotating uniform field can be produced within the region bounded by the surface S by producing on this surface a potential distribution which satisfies the relation

$$V_g = V \cos (\theta - \omega t) \quad (4)$$

where V_g is the potential on the surface.

Equation 4 can be written in the form

$$V_g = (V \cos \omega t) \left(\frac{1 + \cos \theta}{2} \right) + (-V \cos \omega t) \left(\frac{1 - \cos \theta}{2} \right) + (V \sin \omega t) \left(\frac{1 + \sin \theta}{2} \right) + (-V \sin \omega t) \left(\frac{1 - \sin \theta}{2} \right) \quad (5)$$

From Equation 5 it will be seen that the requisite potential distribution over the surface S, to produce the rotating uniform field, can be obtained by a composite or mosaic electrode comprising a set of four electrode elements, the relative areas of the elements being given by the θ terms in the equation so that the contribution factors of the elements to the gross potential are as given by these terms, and the potentials applied to the electrode elements being given by the ωt terms in the equation. The potentials, it will be noted, are obtainable from two alternating current sources 90 degrees out of phase.

A suitable composite or mosaic structure is illustrated in Fig. 2, the constituent electrode elements being shown in developed form. It comprises electrode elements A and B varying in width according to the relations

$$\left(\frac{1 + \cos \theta}{2} \right) \text{ and } \left(\frac{1 - \cos \theta}{2} \right)$$

respectively, connected to the terminals of a source 16 producing a voltage $V \cos \omega t$, and the electrode elements C and D varying in width according to the relations

$$\left(\frac{1 + \sin \theta}{2} \right) \text{ and } \left(\frac{1 - \sin \theta}{2} \right)$$

respectively, connected to the terminals of a source 17 producing a voltage $V \sin \omega t$.

The composite or mosaic electrode 14 in the device shown in Fig. 1 comprises one or more sets of electrode elements of the construction

illustrated in Fig. 2, the number of sets in any case being determined by the axial length of the region throughout which the rotating uniform field is desired. The composite or mosaic electrode 14 is effective to rotate the beam emanating from the electron gun 11, 12, about the longitudinal axis of the electrode 14, so that the beam impinges upon the target electrodes or anodes 13 in succession. In a particularly advantageous and efficient construction wherein end effects are minimized, the length of the composite electrode is at least twice as great as the diameter of this electrode and the combined width of the set of four electrode elements is less than the radius of the composite electrode.

The composite or mosaic electrode 14 may be utilized also in devices of constructions other than that illustrated in Fig. 1. For example, it may be employed in place of crossed pairs of sweep-plates in oscillograph and television devices in which case the two signals, usually applied between the sweep-plates, are applied to the electrode elements constituting the composite or mosaic electrode. In another construction, illustrated in Fig. 4, the composite electrode 14 is utilized in conjunction with a cathode 18 to produce a rotating sheet beam of electrons, indicated by the lines T. The cathode 18 may be of the equipotential type, is linear and extends along the axis of and within the electrode 14. Mounted within the composite electrode 14 and parallel to the longitudinal axis thereof are a plurality of linear target electrodes 19.

The cathode 18 is biased positive with respect to most of the surface of the mosaic electrode 14, as by a battery 20, so that there is produced a radial, focussed sheet beam of electrons in the instantaneous direction of the electric field, the beam rotating with the field and the electrode elements constituting the mosaic being energized, in the manner illustrated in Fig. 2, from two alternating current sources, 90 degrees out of phase, through suitable transformers 21. The beam impinges upon the target electrodes 19, whereby sharp current impulses are produced in a circuit connected to the target electrodes 19 through a transformer 22. The target electrodes 19 may be connected together and to a common output circuit or, if desired, may be electrically separate and each connected to an individual output circuit as, for example, in time multiplex transmission systems.

In the embodiment of this invention illustrated in Fig. 5, the mosaic or composite electrode comprises a multiplicity of parallel wires 23 mounted in a cylindrical boundary and parallel to the longitudinal axis of this boundary. The wires are divided electrically into four groups, the wires of each group being connected by the wires 24. In the drawings, Fig. 5, the wires of the several groups are designated as A', B', C' and D'. The number of wires 23 in each group varies with the angle θ according to Equation 5, the four groups being energized in pairs, as described in connection with Figs. 1 and 2, by the alternating current sources 16 and 17. Thus, for example, the number of wires 23 in the A' group varies according to the relation

$$\left(\frac{1 + \cos \theta}{2} \right)$$

and the number of wires in each of the other groups varies according to the corresponding θ term in Equation 5.

In the constructions illustrated in Figs. 7 and 8, the electrode elements constituting the com-

posite or mosaic electrode are interleaved and the spacial variation of resultant potential to produce a rotating uniform field is realized by constructing and arranging the electrodes so that the electrode elements shield one another and the degree of shielding varies to produce a corresponding variation in the gross potential over the surface of the mosaic.

The composite or mosaic electrode illustrated in Fig. 7 comprises a plurality of circular wire rings electrically connected in four groups, A², B², C² and D², by tie wires 25, the several wire rings being in interleaved relation and each wire ring being offset with respect to the adjacent wire or wires. The four groups are connected to the terminals of two alternating current sources 16 and 17, 90 degrees out of phase, as shown in Fig. 6. As will be apparent from Figs. 6 and 7, each of the wires of each group is shielded by the wires of the other groups and the shielding of the several wires varies around the region bounded by the composite electrode. Thus, considering θ taken as indicated in Fig. 6, at θ equal to zero, the wires of group A² are completely shielded by the wires of the other three groups; at

$$\theta = \frac{\pi}{2}$$

the wires of group B² are completely shielded; at $\theta = \pi$, the wires of group C² are completely shielded; at

$$\theta = \frac{3\pi}{2}$$

the wires of group D² are completely shielded.

At other values of θ , the contributions of the several wires of the groups to the resultant potential distribution adjacent the inner boundary of the mosaic or composite electrode vary substantially according to the θ terms in Equation 5. Specifically, the contribution factors of the several wires are substantially in the relation given below:

$$\text{Group A}^2 - \frac{1 - \cos \theta}{2}$$

$$\text{Group B}^2 - \frac{1 - \sin \theta}{2}$$

$$\text{Group C}^2 - \frac{1 + \cos \theta}{2}$$

$$\text{Group D}^2 - \frac{1 + \sin \theta}{2}$$

Hence, when the wires are energized, the mosaic or composite electrode produces a radial uniform rotating field. The composite electrode illustrated in Figs. 6 and 7 may be utilized in the same manner as that shown in Figs. 1 and 2 and described heretofore.

The composite or mosaic electrode illustrated in Fig. 8 is generally the same as that shown in Fig. 7 differing therefrom principally in that the electrode elements are circular metallic discs 26 provided with eccentric circular apertures, mounted in pile-up relation and insulated from one another by insulating washers 27. The form and relation of the discs is shown in Figs. 8A to 8D, the letter character in these figures corresponding to the group letter employed in Figs. 6 and 7. The discs 26 and insulating washers 27 are held in assembled relation by metallic pins 28 each of which extends through oversized apertures 29 in the discs of three groups and closely

fits apertures 30 in the discs of the fourth group whereby the discs of each group are connected together electrically. The composite electrode illustrated in Fig. 8 may be employed in the same manner as that shown in Figs. 1 and 2.

Although specific embodiments of this invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A composite electrode system for electron discharge devices comprising a plurality of electrode elements mounted adjacent one another and bounding a substantially cylindrical space, means connecting said electrode elements electrically into two pairs of groups in which the electrode elements of each group are interleaved with those of the other groups, means for impressing an alternating potential between one of said pairs, and means for impressing an alternating potential 90 degrees out of phase with said first potential between the other of said pairs, said electrode elements being so constructed and arranged that upon the application of said potentials thereto the resultant field produced is radial with respect to the longitudinal axis of said space and rotates about said axis.

2. A composite electrode system for electron discharge devices comprising a plurality of electrode elements mounted in close space relation and bounding a substantially cylindrical space, means electrically connecting said elements into two pairs in which the elements of each pair are interleaved with those of the other, means for impressing an alternating potential between the elements of one pair, and means for impressing an equal alternating potential 90 degrees out of phase with said first potential between the elements of the other pair, said electrode elements being so constructed and arranged that the potential contribution factors of the elements of one pair to the gross potential of the system are proportional to

$$\left(\frac{1 - \cos \theta}{2}\right) \text{ and } \left(\frac{1 + \cos \theta}{2}\right)$$

respectively and the potential contribution factors of the elements of the other pair are proportional to

$$\left(\frac{1 - \sin \theta}{2}\right) \text{ and } \left(\frac{1 + \sin \theta}{2}\right)$$

respectively, where θ is the angle measured around the longitudinal axis of said cylindrical space.

3. A composite electrode system for electron discharge devices comprising four annular electrode elements mounted in superimposed closely adjacent relation and bounding a cylindrical space, means for impressing an alternating potential between one pair of alternate electrode elements, and means for impressing an equal alternating potential 90 degrees out of phase with said first potential between the other pair of alternate electrode elements, said electrodes being so constructed and arranged that upon the application of said potentials thereto the resultant potential along the boundary of said space varies according to the relation

$$V_g = V \cos (\theta - \omega t)$$

where V_g is said resultant potential, V is the maximum value of said alternating potentials, θ

is the angle measured along said boundary about the longitudinal axis thereof, t is time and ω is 2π times the frequency of said alternating potentials.

4. A composite electrode system for electron discharge devices comprising a set of four electrically individual coaxial cylindrical electrode elements mounted in closely adjacent edge-to-edge relation, each of said electrode elements varying in area according to a corresponding one of the relations

$$\left(\frac{1+\cos \theta}{2}\right), \left(\frac{1-\cos \theta}{2}\right), \left(\frac{1+\sin \theta}{2}\right), \text{ and } \left(\frac{1-\sin \theta}{2}\right)$$

where θ is the angle along the inner surface of the electrode element taken with respect to a common radius for all of said elements.

5. A composite electrode system for electron discharge devices comprising a plurality of sets of four cylindrical electrode elements, said elements being mounted in coaxial, edge-to-edge relation, juxtaposed edges of adjacent electrodes conforming to one another, means electrically connecting corresponding electrode elements of said sets together into four groups, and the electrode elements in each group varying in area according to a corresponding one of the relations

$$\left(\frac{1+\cos \theta}{2}\right), \left(\frac{1-\cos \theta}{2}\right), \left(\frac{1+\sin \theta}{2}\right), \text{ and } \left(\frac{1-\sin \theta}{2}\right)$$

where θ is the angle measured along said elements from a radial reference plane, common to all of said elements.

6. A composite electrode system for electron discharge devices comprising a set of four cylindrical electrode elements mounted in closely adjacent edge-to-edge relation and bounding a cylindrical surface, means for impressing an alternating potential between one pair of alternate electrode elements, means for impressing between the other pair of alternate electrodes an alternating potential equal to and 90 degrees out of phase with said first potential, the juxtaposed edges of adjacent electrode elements conforming to one another, and each of said elements varying in width, as measured parallel to the longitudinal axis of said surface such that the resultant potential along said surface varies substantially according to the relation

$$V_g = V \cos (\theta - \omega t)$$

where V_g is the resultant potential, V is the maximum value of said alternating potentials, θ is the angle along said surface measured about said axis, ω is 2π times the frequency of said alternating potentials and t is time.

7. An electron discharge device comprising a cylindrical composite electrode, a cathode en-

compassed by and substantially coaxial with said composite electrode, a plurality of target electrodes between said cathode and said composite electrode, said composite electrode comprising a set of four annular electrode elements mounted in closely adjacent relation, means for impressing an alternating potential between one pair of alternate electrode elements, and means for impressing between the other pair of alternate electrode elements an alternating potential equal to and 90 degrees out of phase with said first alternating potential, said electrode elements being so constructed and arranged that upon application of said potentials thereto the resultant potential along the inner boundary of said composite electrode varies according to the relation

$$V_g = V (\cos \theta - \omega t)$$

where V_g is said resultant potential, V is the maximum value of said alternating potentials, θ is the angle along said boundary measured about the longitudinal axis thereof, ω is 2π times the frequency of said alternating potentials, and t is time.

8. An electron discharge device in accordance with claim 7 wherein said electrode elements are cylindrical and mounted in edge-to-edge relation, juxtaposed edges of adjacent elements conform to one another, and each of said elements varies in width about said axis according to a corresponding one of the relations

$$\left(\frac{1+\cos \theta}{2}\right), \left(\frac{1-\cos \theta}{2}\right), \left(\frac{1+\sin \theta}{2}\right), \text{ and } \left(\frac{1-\sin \theta}{2}\right)$$

9. A composite electrode system for electron discharge devices comprising a set of four electrode elements mounted in superimposed relation, each of said elements having a circular aperture therein, means for impressing an alternating potential between one pair of alternate elements, and means for impressing an alternating potential 90 degrees out of phase with said first potential between the other pair of alternate elements, the apertures in said elements being offset such that the contribution factor of each of said elements to the resultant potential within said system is given by the corresponding one of the relations

$$\left(\frac{1+\cos \theta}{2}\right), \left(\frac{1-\cos \theta}{2}\right), \left(\frac{1+\sin \theta}{2}\right), \text{ and } \left(\frac{1-\sin \theta}{2}\right)$$

where θ is the angle measured about the axis of the electrode system.

10. A composite electrode system in accordance with claim 9 wherein said electrode elements are eccentrically apertured discs mounted in coaxial relation.

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