Sept. 10, 1946. A. M. SKELLETT 2,407,296

ELECTRIC DISCHARGE APPARATUS

Filed Feb. 5, 1941

FIG. 1

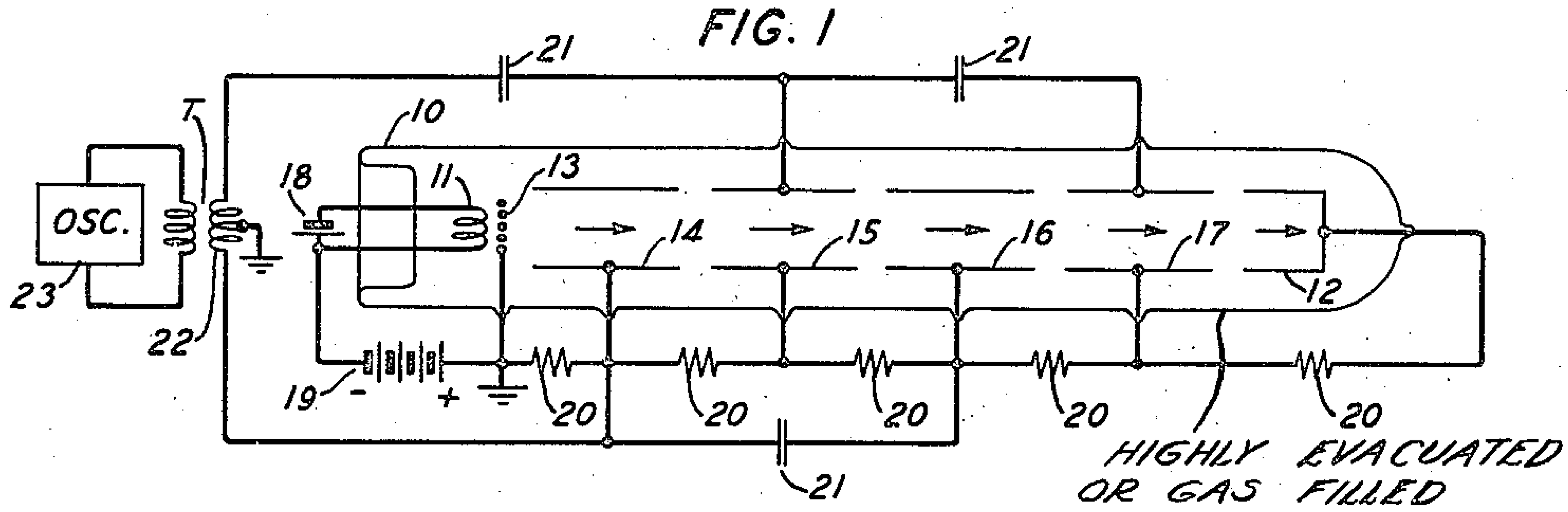



FIG. 3

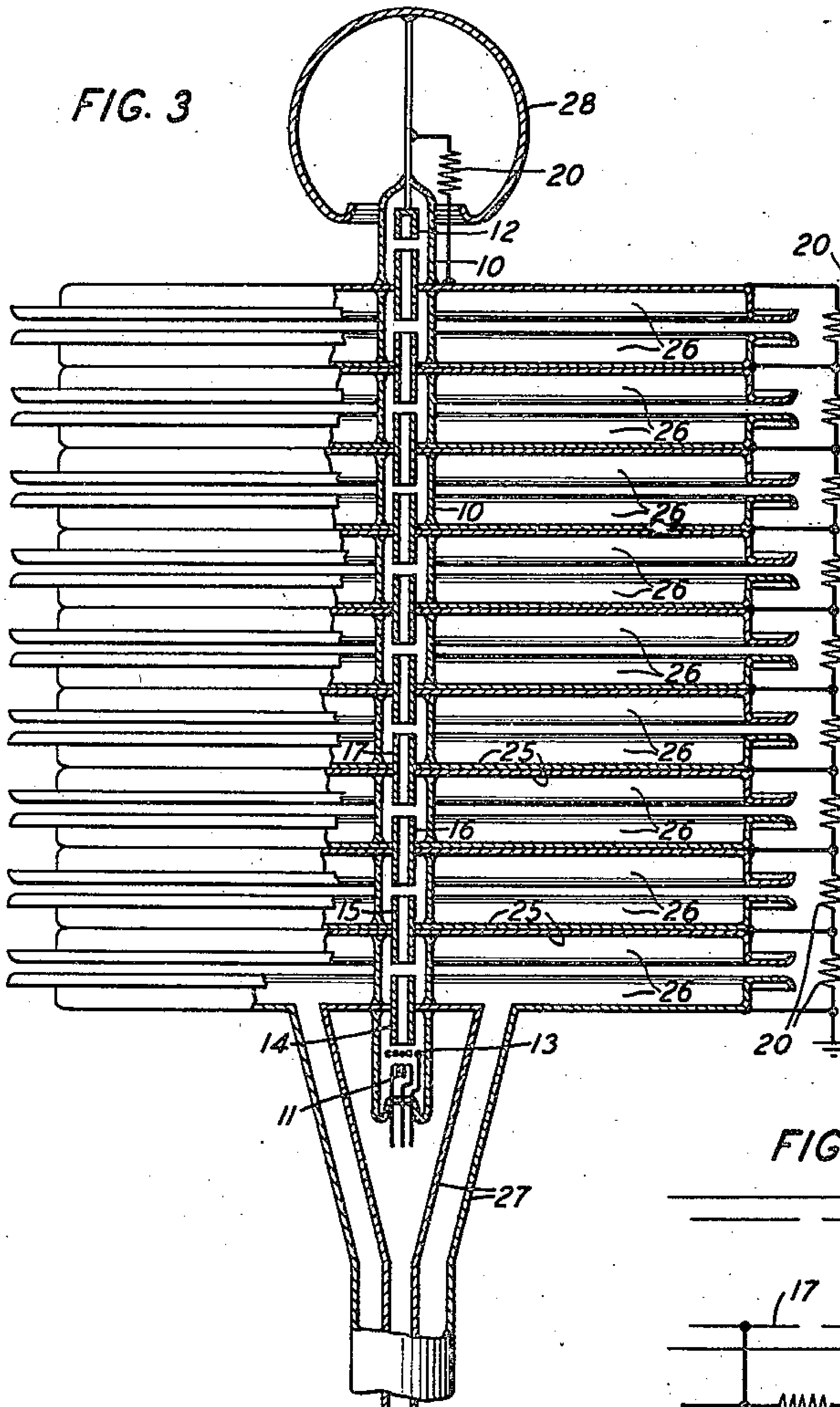


FIG. 2

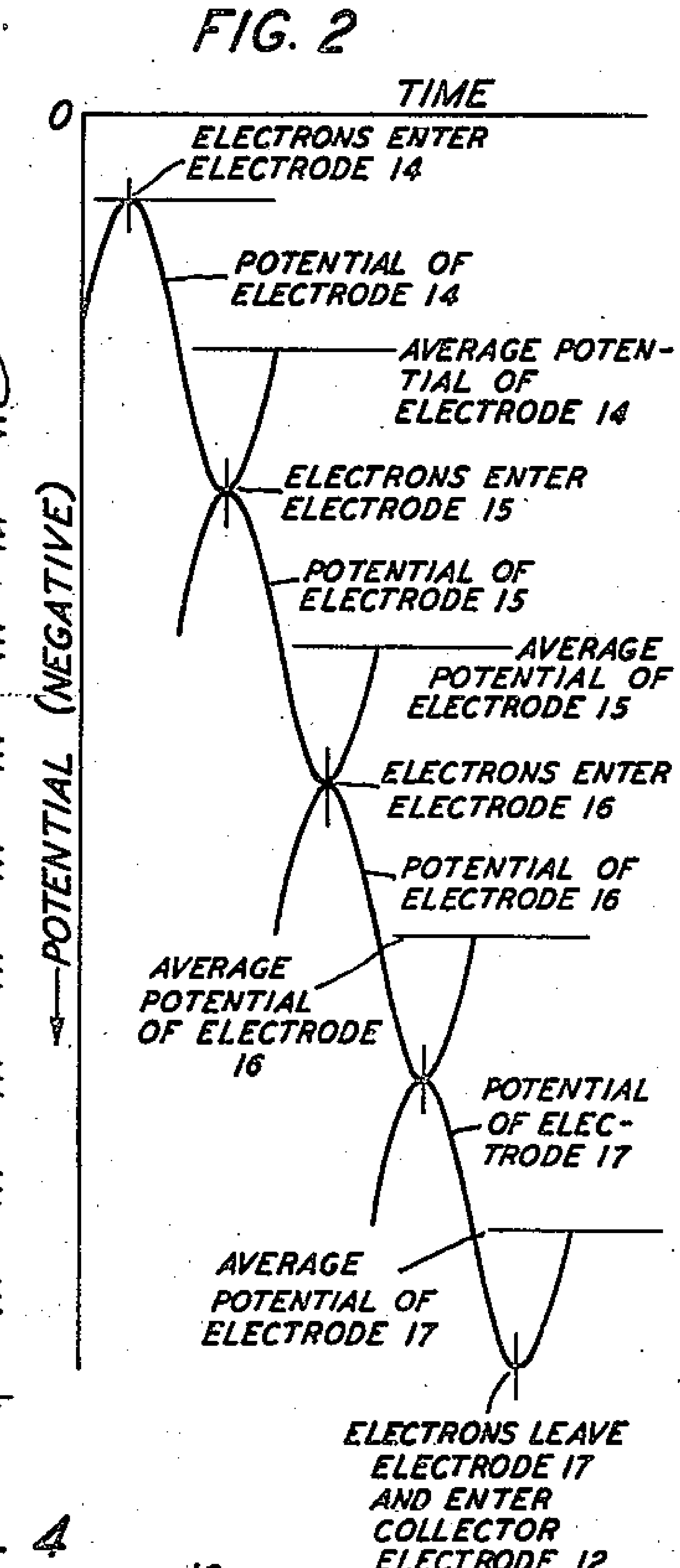
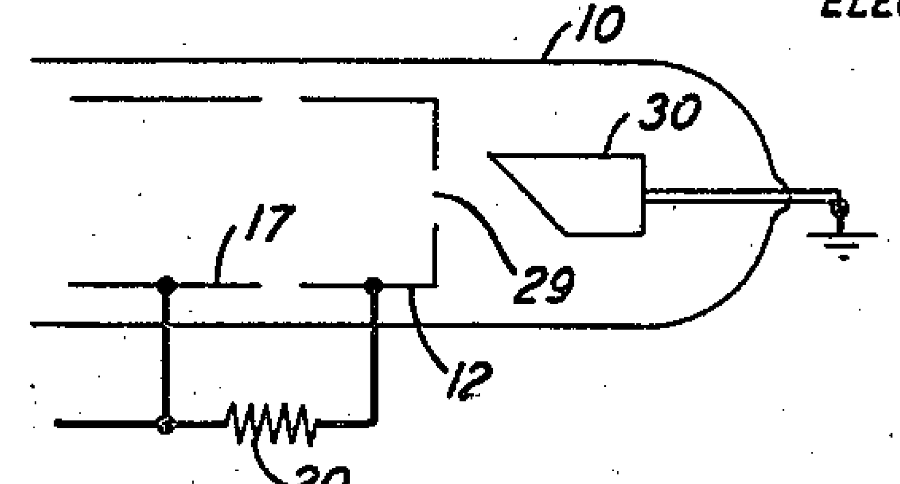



FIG. 4



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2,407,296

## ELECTRIC DISCHARGE APPARATUS

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13 Claims. (Cl. 315—14)

1

This invention relates to electric discharge apparatus and more particularly to apparatus for and a method of electronically generating high potentials.

One general object of this invention is to enable the facile and efficient generation of high potentials.

In one illustrative embodiment of this invention, an electron stream is projected through a series of cylindrical electrodes mounted in coaxial and end-to-end relation, the cylindrical electrodes being so constructed and energized that in passing through each of these electrodes, the electrons in the stream obtain an increase in their potential energy without substantial net change in their kinetic energy. The stream, after its passage through the series of cylindrical electrodes, impinges upon a target or collector electrode to which it transfers its energy whereby the target or collector electrode becomes of a high negative potential relative to the source of the electron stream.

The invention and the various features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing, in which:

Fig. 1 is a diagrammatic view of electron discharge apparatus illustrative of one embodiment of this invention;

Fig. 2 is a diagram illustrating the relation between the potentials of the various electrodes in the apparatus shown on Fig. 1 and time of the electron stream as it traverses the device;

Fig. 3 is an elevational view partly in section of electron discharge apparatus illustrative of another embodiment of this invention; and

Fig. 4 is a fragmentary view showing a modification of the embodiment of this invention illustrated in Fig. 1.

Referring now to the drawing, the apparatus illustrated in Fig. 1 comprises an elongated evacuated enclosing vessel 10, a cathode 11 at one end of the vessel, a cup-shaped target or collector electrode 12 at the other end of the vessel and in alignment with the cathode 11, and an accelerating electrode or grid 13 adjacent the cathode 11. Mounted between the cathode 11 and the target or collector electrode 12 and in coaxial, equally spaced end-to-end relation are a plurality of identical cylindrical electrodes 14 to 17, inclusive.

The cathode 11 is energized by a suitable source, such as a battery 18, to cause copious emission of electrons therefrom, the electrons being accelerated away from the cathode by the

2

accelerating electrode or grid 13, which is maintained at a relatively low positive potential, for example, of the order of 100 volts, with respect to the cathode, as by a battery 19. The target or collector electrode 12 and the cylindrical electrodes 14 to 17 are connected to one another through suitable resistances 20, as shown. The cylindrical electrodes are connected in two groups, 14, 16 and 15, 17, through suitable condensers 21, the two groups being connected to opposite ends of the secondary winding 22 of a transformer T, the primary winding of which is connected to an oscillator 23 for producing a sinusoidal potential. The mid-point of the secondary winding 22 and the accelerating electrode or grid 13 may be grounded as shown.

As shown in Fig. 2, the alternating current potentials of successive cylindrical electrodes are substantially equal and 180 degrees out of phase. Thus, for example, when the alternating current potential of the electrodes 14 and 16 is decreasing the alternating current potential of the electrodes 15 and 17 is increasing. The length of the cylindrical electrodes and the frequency of the oscillator 23 are so related together with the accelerating potential on the grid 13 that the time of electron travel from one gap between two successive cylindrical electrodes to the next gap is equal to one-half period of the alternating potential. This relation may be expressed mathematically as

$$F=\frac{2.97\times10^{7}\times V^{1/2}}{L}$$

where F is the frequency of the oscillator in cycles per second, V is the accelerating potential in volts, and L is the distance between the centers of successive cylindrical electrodes in centimeters.

At the beginning of operation of the device, the average potentials of the cylindrical and collector electrodes are zero. The electrons emanating from the cathode 11 are accelerated by the accelerating electrode or grid 13 and enter the first cylindrical electrode 14 when the potential of the electrode 14 is substantially the same as that of the grid 13. When the electrons are inside of the electrode 14, the potential of the electrode 14 swings negative, as shown in Fig. 2. At the same time, as pointed out above, the potential of the second cylindrical electrode is increasing so that when the electrons have traversed the first cylindrical electrode 14 and reach the gap between the electrodes 14 and 15, these two electrodes are at the same potential. Consequently, the electron velocity at this gap is the same as the velocity of the electrons entering the first cylindrical electrode 14 and the kinetic energy of the electrons in passing through the electrode 14 remains unchanged. However, as the electrons pass through the electrode 14, their potential energy is increased, the necessary power for the work done being supplied by the oscillator 23.

In a like manner, as the electrons pass through each of the succeeding cylindrical electrodes they obtain an increase in their potential energy without change in their kinetic energy. Hence, at each cylindrical electrode the electrons are carried further negative, as illustrated in Fig. 2. The electrons emerging from the final cylindrical electrode 17 are travelling at their initial velocity and flow to the target or collector electrode 12 where their energy is expended and, as a result, the target or collector electrode is charged to or maintained at a high negative direct current potential with respect to the cathode 11. The magnitude of this potential will be dependent upon the number of cylindrical electrodes employed, and the maximum value thereof, in general, is given by the relation

$$P=2.8nE+V$$

where P is the potential, $n$ is the number of cylindrical electrodes, E is the R. M. S. value of the oscillating potential of the cylindrical electrodes and V is the accelerating potential on the grid 13.

When the electrons arrive at the target or collector electrode 12 and charge it negatively as described above, current passes back to ground through the resistances 20 so that the average potentials upon the cylindrical electrodes are adjusted whereby the electrodes 14 to 17 are made successively more negative than the next preceding electrode and the potentials of these electrodes are as illustrated in Fig. 2.

The apparatus may be utilized to generate high potentials or for other purposes. For example, it may be utilized as a detector. If a radio frequency input, for example in the megacycle range, is supplied by the oscillator 23, the direct current potential of the target or collector electrode 12 will be proportional to the magnitude of the radio frequency input. If the radio frequency input is modulated, the direct current potential of the target or collector electrodes will vary in accordance with the modulating signal so that detection with amplification is obtained.

It will be understood, of course, that the condensers 21 should be of such capacitance that the several radio frequency circuits are tuned to the operating frequency whereby high efficiency operation is realized.

The apparatus may be utilized also to generate X-rays. For example, in one form suitable for this purpose illustrated in Fig. 4, the electrode 12 is provided with a central aperture 29 through which the electron stream passes. The stream then impinges upon the target 30, connected to ground as shown. In traversing the space between the electrodes 12 and 30, the electrons passing through the aperture 29 have their potential energy converted into kinetic energy and, hence, will generate X-rays when they impinge upon the target 30.

In the embodiment of the invention illustrated in Fig. 3, the several cylindrical electrodes are mounted in coaxial end-to-end relation and supported by annular dished metallic members 25 sealed to and extending through the wall of the



vitreous enclosing vessel 10, and the several cylindrical electrodes are electrically associated by coupled annular cavity resonators 26 each of which includes a pair of the dished metallic members 25 spaced at their peripheries and connected as shown. Each cavity resonator is of a diameter substantially equal to one wave length of the operating frequency of the apparatus and the several resonators are so constructed that the alternating potentials of successive cylindrical electrodes are 180 degrees out of phase, as in the apparatus disclosed in Fig. 1. The first cavity resonator, that is, the one nearest the cathode 11 is energized through a coaxial line 27 coupled to an oscillator, the resonators being tuned to the frequency of the oscillator. The operation of the apparatus illustrated in Fig. 3 is basically the same as that of the apparatus shown in Fig. 1 and described heretofore. The target or collector electrode 12 may have a shield terminal 28 connected thereto as shown. The members 25 of the various resonators may be provided with apertures, not shown, to vary the coupling between the resonators.

In both embodiments of the invention illustrated and described either electrostatic or magnetic focussing of the electron stream may be employed. For example, if the cylindrical electrodes are so constructed and arranged that the potential curves of adjacent electrodes overlap to a small extent, the gaps between adjacent electrodes will act as double positive electronic lenses and the electrons focussed along the axis thereby. Magnetic focussing may be obtained by suitable magnets exterior to the enclosing vessel 10.

Although in the embodiments of the invention shown and described, electron streams are utilized, the invention may be practiced also by causing a stream of ions to flow through the series of cylindrical electrodes energized in the same manner as in the embodiments of the invention described hereinabove. When ion streams are employed, the operating frequencies in most cases will be in the kilocycle range. The ion streams may be focussed in the same manner as the electron streams.

Also, although the invention has been described with particular reference to devices of the high vacuum type, i. e., devices wherein the enclosing vessel is evacuated to a high degree, it may be embodied also in gaseous discharge devices. For example, the enclosing vessel 10 in the apparatus shown in Figs. 1 and 3 may have therein a filling of a suitable gas at such pressure that the ion current is less than the electron current. During operation of such device, both the ions and electrons travel in the same direction, that is toward the target or collector electrode 12, and impinge upon the target or collector electrode.

It will be understood that the specific embodiments of the invention shown and described 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. The method of generating a potential which comprises producing a stream of charged particles, accelerating said particles, projecting the accelerated particles toward a target, maintaining in the space traversed by said particles in flowing toward said target an electrostatic field increasing toward said target, impressing upon adjacent regions of said space an alternating

electric field, the alternating field in each region being substantially 180 degrees out of phase with the alternating field in the adjacent region, and collecting said particles at said target.

2. The method of generating a potential which comprises producing a stream of electrons, accelerating the electron stream, projecting the accelerated electron stream toward a target, producing in a series of successive regions along the path along which the stream is projected alternating electric fields such that the alternating field in each region is substantially 180 degrees out of phase with the alternating field in the adjacent region, maintaining in each of said regions an electrostatic field component greater negatively than in the next preceding region, whereby in traversing said series of regions said electrons gain an increase in their potential energy without substantial change in their kinetic energy, and collecting said electrons after they have traversed said series of regions.

3. The method of generating a potential which comprises producing a stream of charged particles, projecting said stream through a time gradient of electric potential, subjecting said particles while traversing said time gradient to a direct current electrostatic field increasing in the direction of projection of said stream to maintain the velocity of said particles substantially constant, and then collecting said particles.

4. The method of generating a potential which comprises producing a stream of electrons, projecting said stream through an electrostatic field of increasing negative potential in the direction of projection of said stream, maintaining in the region of said field traversed by said stream a time gradient of electric potential related to said electrostatic field to maintain the velocity of said electrons substantially constant, and collecting said electrons after they have traversed said field.

5. Electric discharge apparatus comprising a target electrode, means projecting a stream of charged particles toward said target electrode, and means for increasing the potential energy of said particles in said stream in their travel to said target electrode while maintaining the velocity of said stream substantially constant, said last means including electrodes and energizing means therefor for producing a time gradient of electric potential through which said stream passes in flowing to said target electrode.

6. Electron discharge apparatus comprising a cathode, means for accelerating the electrons emanating from said cathode, a target electrode for receiving the electrons, and means including spaced electrodes between said cathode and said target electrode and radio frequency energizing means therefor for increasing the potential energy of said electrons in their travel to said target electrode without substantially altering the velocity thereof.

7. Electric discharge apparatus comprising a collector electrode, a source of charged particles, means for accelerating said particles toward said collector electrode, a pair of coaxial cylindrical electrodes mounted in end-to-end relation between said source and said collector electrode, means for increasing the energy of said particles in passing through said cylindrical electrodes including a source impressing a radio frequency potential between said coaxial electrodes, resistance means connecting said coaxial electrodes to one another and to said accelerating means, and an additional resistance means directly connected between said collector electrode and the coaxial electrode nearest thereto.

8. Electron discharge apparatus comprising a cathode, an accelerating electrode in cooperative relation with said cathode, means maintaining said electrode at a positive potential with respect to said cathode, a collector electrode, a pair of coaxial cylindrical electrodes mounted in end-to-end relation between said accelerating and collector electrodes, resistances connecting said coaxial electrodes to one another and to said accelerating electrode, an additional resistance connecting said collector electrode to the cylindrical electrode nearest thereto, and means for impressing a radio frequency potential between said coaxial electrodes.

9. Electric discharge apparatus comprising a collector electrode, two groups of cylindrical coaxial electrodes mounted in end-to-end relation and in alignment with said collector electrode, the electrodes of one group being mounted in alternate relation with the electrodes of the other group, means for projecting a stream of charged particles through said coaxial electrodes toward said cellector electrode, means resistively connecting each of said coaxial electrodes to the next succeeding electrode, and a source of high frequency energy impressing a radio frequency potential between said coaxial electrodes such that the potential of one group of said coaxial electrodes is substantially 180 degrees out of phase with the potential of said other group of electrodes.

10. Electron discharge apparatus comprising means for producing a stream of electrical particles, a target electrode for receiving said stream, a plurality of coaxial cylindrical electrodes mounted in end-to-end relation between said means and said target electrode, means for accelerating said stream toward the coaxial electrodes, and means for impressing a high frequency potential between one group of alternate coaxial electrodes and the other of said electrodes, said coaxial electrodes being spaced so that the distance between centers of successive coaxial electrodes is

$$L=\frac{2.97\times10^7\times V^{1/2}}{F}$$

where L is said distance, V is the accelerating potential due to said accelerating means and F is the frequency of said high frequency potential.

11. Electron discharge apparatus comprising a cathode, a collector electrode in alignment with said cathode, an accelerating electrode adjacent said cathode, means maintaining said accelerating electrode at a positive potential with respect to said cathode, two groups of cylindrical electrodes mounted alternately and in coaxial end-to-end relation between said accelerating and collector electrodes, and means for impressing a high frequency potential between said groups of electrodes, each of said cylindrical electrodes having an effective length equal to

$$\frac{2.97\times10^7\times V^{1/2}}{F}$$

where V is the potential of said accelerating electrode and F is the frequency of said high frequency potential.

12. Electron discharge apparatus comprising an enclosing vessel having an ionizable filling therein, a cathode and a target electrode within said vessel, means for accelerating electrons emanating from said cathode toward said target

electrode, a pair of cylindrical electrodes mounted in end-to-end relation between said cathode and said target electrode, resistance means of substantial magnitude connecting said cylindrical and target electrodes to one another, and means for impressing a high frequency potential between said cylindrical electrodes.

13. Electric discharge apparatus comprising an apertured electrode, means for projecting a stream of charged particles toward said apertured electrode, a target electrode facing the face of said apertured electrode remote from the face



toward which said stream is directed, and means for increasing the potential energy of said particles in their travel to said apertured electrode while maintaining their velocity substantially constant, said last means including a series of electrodes between said first means and said apertured electrode and energizing means therefor producing a time gradient of electric potential through which said stream passes in flowing toward said apertured electrode.

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