

Feb. 24, 1942.

J. R. PIERCE

2,274,092

ELECTRON DISCHARGE DEVICE

Filed May 4, 1938

2 Sheets-Sheet 1

FIG. 1

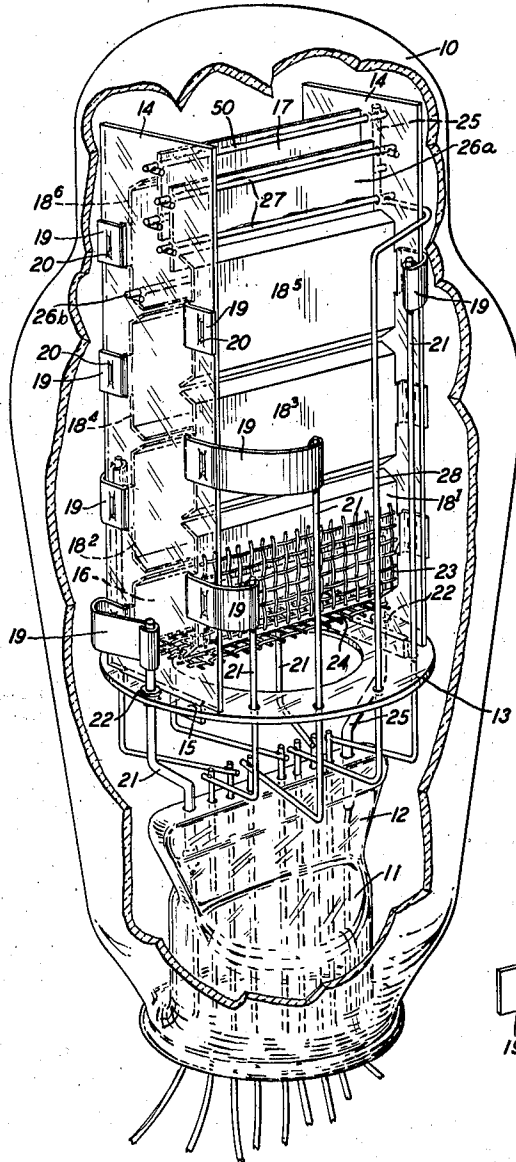


FIG. 2

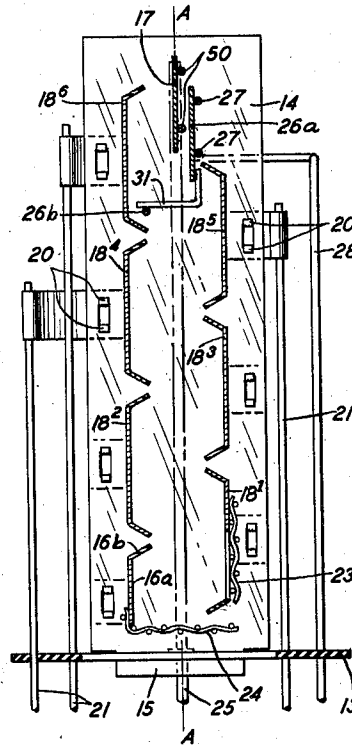
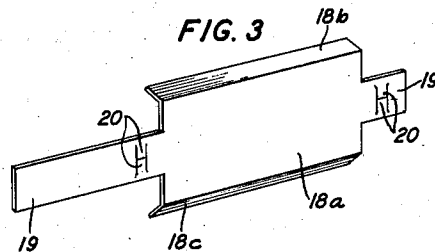


FIG. 3



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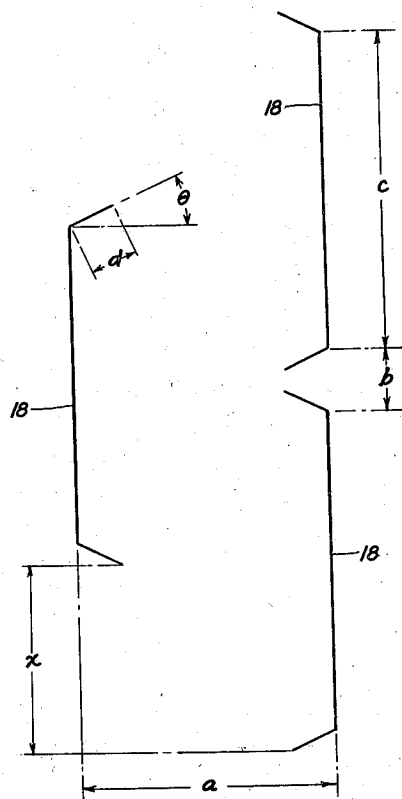


FIG. 4

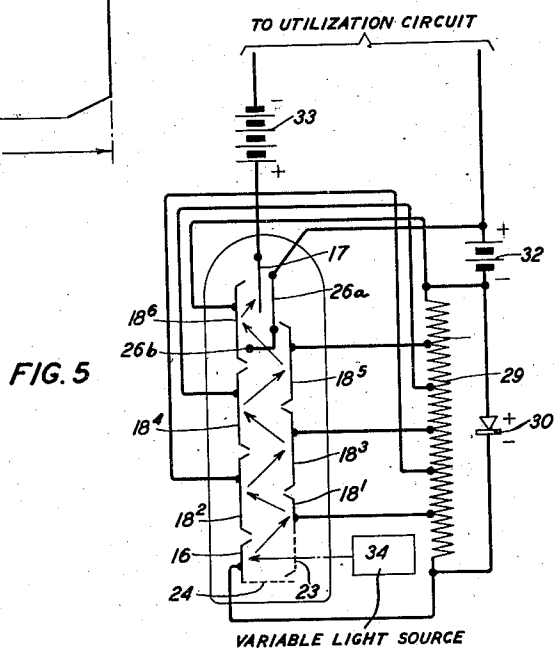


FIG. 5

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2,274,092

ELECTRON DISCHARGE DEVICE

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Application May 4, 1938, Serial No. 205,930

11 Claims. (Cl. 250—175)

This invention relates to electron discharge devices and more particularly to such devices having one or more secondary electron emitting electrodes and generally known as electron multipliers.

In electron multipliers of a type comprehended by this invention, a plurality of successively arranged secondary cathodes are mounted between a primary cathode and an anode or collector electrode and each secondary cathode is adapted to be operated at a potential somewhat higher than that upon the next preceding cathode.

When the primary cathode is energized, the primary electrons emanating therefrom are drawn toward the secondary cathode nearest thereto and cause the emission of secondary electrons from this secondary cathode. Because of the character of the surface of the secondary cathode, each impinging primary electron will result in the release or emanation of a plurality of secondary electrons, so that, in effect, an electron multiplication and, hence, an amplification of the primary current obtains. The secondary electrons thus produced are drawn to the next succeeding cathode and result in the emission of a still greater number of electrons from the latter. This phenomenon is repeated at each of the succeeding secondary cathodes and the electrons emanating from the last secondary cathode flow to the collector electrode or anode and constitute the output current of the electron multiplier.

In an electron multiplier of the type described it has been found that the electrons emanating from each of the cathodes tend to diverge with the result that some of the electrons originating at one cathode may not reach the next succeeding electrode or may impinge upon the next succeeding cathode at portions adjacent which the fields are not conducive to efficient and copious secondary electron emission. Consequently, a low efficiency and unstable and non-uniform operating characteristics may result.

As will be apparent, the electron current increases toward the anode or collector end of the electrode assembly so that undesired space charge effects may be produced which would tend to limit the magnitude of the output current of the multiplier.

One general object of this invention is to increase the efficiency and other operating characteristics of an electron multiplier.

More specifically, objects of this invention are:

To assure convergence of the electrons emanating from the cathodes in an electron multiplier

whereby substantially all of the electrons emanating from each cathode flow to the next succeeding electrode and the electrons arriving at each secondary cathode impinge upon a portion thereof adjacent which fields conducive to efficient and copious secondary electron emission exist;

To achieve such convergence without the use of magnetic or other extraneous fields; and

To obtain increasingly strong fields in the last stages of an electron multiplier so that space charge effects are minimized or prevented and a large output current may be attained.

In accordance with one feature of this invention, the cathodes in an electron multiplier are so shaped and arranged that relatively strong fields obtain away from large areas of the emissive surface thereof and the electrons emanating from each cathode are focussed upon the next succeeding electrode.

In accordance with another feature of this invention, means are provided at the anode or collector electrode end of the electron multiplier for providing relatively strong fields at the last stages, without disturbing the fields at preceding stages, whereby space charge is substantially eliminated and a large output current may be obtained.

The invention and the foregoing 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 a perspective view of an electron multiplier illustrative of one embodiment of this invention, portions of the enclosing vessel being broken away to show details more clearly;

Fig. 2 is a side view partly in section of the electrode assembly included in the electron multiplier shown in Fig. 1;

Fig. 3 is an enlarged perspective view of one of the secondary cathodes;

Fig. 4 is a diagrammatic side view of a portion of the electrode structure illustrated in Fig. 2, showing typical relative dimensions of the electrodes and the spacing thereof; and

Fig. 5 is a circuit diagram illustrating one manner in which the electron multiplier shown in Fig. 1 may be operated.

Referring now to the drawings, the electron multiplier there illustrated comprises a highly evacuated, enclosing vessel, 10 having at one end thereof an inwardly extending stem 11 terminating in a press 12 from which a unitary electrode assembly is supported. This assembly comprises

an insulating frame including an annular spacer 13, for example of mica, and a pair of parallel arms or uprights 14, which may be strips of mica, having extensions or tongues 15 fitted in apertures or slots in the annular spacer 13.

Disposed between the arms or uprights 14 and supported thereby are a primary cathode 16, adjacent one end of the arms or uprights 14, a collector electrode or anode 17, adjacent the other end of the arms or uprights 14, and a plurality of secondary cathodes 18¹ to 18⁶, inclusive. As shown clearly in Fig. 2, the secondary cathodes are mounted in staggered relation in two parallel rows between the primary cathode 16 and the anode or collector electrode 17.

Preferably, the secondary cathodes 18 are substantially identical in configuration and are equally spaced from the medial plane between the two rows, namely, a plane extending through the line A—A in Fig. 2, and the cathodes in each row are equally spaced from one another. Hence, the cathodes 18 have glide plane symmetry with respect to the medial plane; that is, if one row of cathodes were displaced a distance x (see Fig. 4) parallel to the medial plane, each secondary cathode would be exactly opposite a corresponding cathode in the other row. Preferably also, the cathodes 18 are symmetrical with respect to a longitudinal plane normal to the medial plane and also with respect to a lateral plane normal to both the medial and longitudinal planes.

As shown clearly in Fig. 3, each of the secondary cathodes 18² to 18⁶, inclusive, which may be formed of a strip or sheet of metal, for example silver, comprises a central, plane rectangular portion 18a and end barrier or baffle portions 18b and 18c which extend obliquely from the intermediate or central portion 18a and toward the medial plane, as shown, for example, in Fig. 2. The end portions 18b and 18c may be of the same dimensions and extend at the same angle with respect to the central portion 18a.

The opposed faces of the central or intermediate portions 18a of the several cathodes 18 may be treated or coated to render them capable of copious and efficient emission of secondary electrons. For example, these faces may be treated to form a coating or matrix thereon including silver, caesium oxide and some free caesium.

Each of the secondary cathodes 18 may be provided with integral end flanges or arms 19 which extend through suitable slits in the insulating uprights 14 and are locked to the uprights by integral bent tabs 20. One flange or arm 19 of each cathode may be extended and have secured thereto a rigid leading-in conductor 21 rising from the press 12 and extending through the spacer 13. Two or more of the conductors 21 may be securely affixed to the spacer 13 as by eyelets 22.

The secondary cathode 18¹ may be of the same form as the other secondary cathodes and includes a coarse mesh grid or screen portion 23 opposite the primary cathode 16.

The primary cathode 16 has a portion substantially identical with one half of one of the secondary cathodes 18² to 18⁶, inclusive, composed of a plane rectangular section 16a having a photoelectrically active surface, and an obliquely extending end or flange portion 16b. It includes also a screen or grid 24 extending below the secondary cathode 18¹, and is affixed to the uprights 14 in the same manner as the secondary cathodes, electrical connection thereto being

established through one of the leading-in conductors 21.

The anode or collector electrode 17 may be a plane rectangular metallic plate supported by rods or wires 50 extending through and fitted in apertures in the uprights 14. As shown clearly in Fig. 2, the anode or collector electrode is mounted opposite and preferably parallel to the central or intermediate portion 18a of the secondary cathode 18⁶. Electrical connection to the anode or collector electrode 17 may be made through a leading-in conductor 25 secured to one or both of the wires 50.

Mounted adjacent and parallel to the anode or collector electrode 17, and between it and the secondary cathode 18⁵, is an auxiliary electrode 26a, which may be a rectangular metallic plate securely affixed to the uprights 14 by rods or wires 27 and having connected thereto a leading-in conductor 28. A second auxiliary electrode 26b, which may be a linear wire or rod extending between the uprights 14, is mounted adjacent the secondary cathode 18⁶ and may be tied electrically to the auxiliary electrode 26a by a conductor 31.

During operation of the electron multiplier, as illustrated in Fig. 5, each of the secondary cathodes 18 may be maintained at a positive potential with respect to the next preceding cathode. For example, each secondary cathode may be maintained of the order of ninety to one hundred twenty-five volts positive with respect to the next preceding cathode. The requisite potentials may be obtained from a potentiometer arrangement including a resistance 29 in shunt with a source, such as a rectifier 30.

The auxiliary electrodes 26a and 26b are maintained positive, for example, double the potential difference between successive cathodes, with respect to the last secondary cathode 18⁶, the potential therefor being obtained from a source such as a battery 32.

The anode or collector electrode 17 may be biased at a positive potential between that of the secondary cathode 18⁶ and the auxiliary electrodes 26, as by a battery 33.

When the primary cathode 16 is energized, as by a beam of light emanating from a source 34 of light of fixed or variable intensity, photo or primary electrons are emitted from the active surface thereof. These electrons, under the influence of the fields extant between the primary cathode and the secondary cathode 18¹ are accelerated toward and impinge upon this secondary cathode and cause the emission of secondary electrons therefrom. Inasmuch as the inner surface of the cathode 18¹ is treated or coated as described heretofore, the secondary electron current therefrom will be several times greater than the impinging primary electron current. Hence, in effect, an electron multiplication and, accordingly, an amplification of the signal corresponding to the light beam emanating from the source 34 occurs.

The secondary electrons produced at the secondary cathode 18¹ are accelerated toward and impinge upon the next secondary cathode 18², whereby a further multiplication and amplification are achieved.

This phenomenon is repeated at each of the succeeding secondary cathodes and the secondary electrons emitted by the cathode 18⁶ flow to the anode 17 and constitute the output current.

The direction of the various electron streams

is indicated by the arrows between electrodes in Fig. 5.

As noted heretofore, it has been found that secondary electrons emanating from electrodes in electron multipliers exhibit a tendency to diverge. In devices constructed in accordance with this invention, however, the secondary electrons emanating from each secondary cathode are strongly converged so that those emanating from each cathode flow to and impinge upon a restricted portion of the next succeeding electrode. This convergence is attributable primarily to the shape of the electrodes which results in the production of such fields adjacent each of the cathodes that the emanating electrons are accelerated away from the cathode at which they originate and directed, by an electron focussing action, upon the next succeeding electrode. It may be noted, in addition, that each flange 18b screens the corresponding portion 18a from the adjacent cathode 18 so that the latter will not produce a retarding field effect adjacent said portion 18a.

The degree of convergence is dependent upon the spacing of the electrodes and the relative dimensions thereof. Typical critical dimensions are indicated in Fig. 4 where

$a=8$ units

$b=2$ units

$c=10$ units

$d=1\frac{1}{2}$ units and

$\theta=25$ degrees.

It will be appreciated that at the anode or collector end of the electrode structure, the interstage electron currents are relatively large so that there is danger of the establishment of deleterious space charge. The establishment of such space charge is prevented by the auxiliary electrodes 26. The auxiliary electrode 26a produces a strong field away from the secondary cathode 18⁵, which is greater than that away from the secondary cathode 18⁴ but less than that away from the cathode 18⁶. The auxiliary electrode 26b augments this field to some extent although it is somewhat shielded electrically from the cathode 18⁵ by the cathode 18⁶. It is almost completely shielded from cathode 18⁴ by cathode 18⁶.

Because of the large current emanating from the cathode 18⁶, a very strong field away therefrom, greater than away from the cathode 18⁵, is required. Such strong field is produced by the anode or collector electrode 17 and the auxiliary electrodes 26.

The fields in the vicinity of the secondary cathode 18⁴ and the preceding cathodes are substantially unaffected by the auxiliary electrodes. Hence, there are achieved, in accordance with this invention, fields of increasing intensity in the last few stages of the electron multiplier without disturbing the fields in the preceding stages.

Although a specific embodiment of this invention has been shown and described, it will be understood that it is 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. An electron multiplier comprising a primary cathode, a collector electrode spaced from said primary cathode, an auxiliary cathode opposite and partially overlapping said primary cathode and having a secondary electron emissive portion obliquely aligned with said primary cathode and a barrier portion extending toward said primary

cathode, a second auxiliary cathode obliquely opposite said first auxiliary cathode and including a secondary electron emissive surface substantially parallel to said emissive portion and an end portion extending toward and overlapping said emissive portion, said barrier and end portions terminating short of the medial plane between said auxiliary cathodes and opposite substantially the center of said primary cathode and said first auxiliary cathode, respectively.

2. An electron multiplier comprising a primary cathode, a collector electrode spaced from said cathode, a plurality of spaced auxiliary electrodes between said cathode and said collector electrode having secondary electron emissive surfaces facing in the same direction, a plurality of other auxiliary electrodes opposite said first auxiliary electrodes and having secondary electron emissive portions opposite and in staggered relation to said surfaces, and barrier means integral with and extending obliquely from the end of each of said emissive surfaces and portions nearest said collector electrode toward the opposite succeeding electrode.

3. An electron multiplier comprising a primary cathode, a collector electrode spaced from said primary cathode, a plurality of auxiliary electrodes successively mounted in staggered relation between said cathode and said collector electrode, each of said auxiliary electrodes having a portion adapted to emit secondary electrons, a barrier member extending obliquely from an edge of each of said portions toward the next preceding electrode, and a baffle member adjacent the opposite edge of each of said portions and extending toward the next succeeding electrode, each baffle member being integral with a corresponding one of said portions.

4. An electron multiplier comprising a primary cathode, a collector electrode, a row of auxiliary electrodes having secondary electron emissive surfaces, mounted between said cathode and said collector electrode, a second row of auxiliary electrodes opposite said first row having secondary electron emissive surfaces in staggered and overlapping relation with said first surfaces, and plate-like flange means integral with each of said auxiliary electrodes and directed toward the next succeeding auxiliary electrode for focussing the electrons emanating from the emissive surfaces thereof upon the next succeeding electrode.

5. An electron multiplier comprising a primary cathode, a collector electrode, and a plurality of auxiliary cathodes successively mounted in staggered relation between said primary cathode and said collector electrode, each of said auxiliary electrodes having a secondary electron emissive portion, a barrier member electrically integral with and extending from one extremity of said portion and a baffle member electrically integral with and extending from the opposite extremity of said portion, and said barrier and baffle members extending toward the medial plane extending between said staggered auxiliary cathodes.

6. An electron multiplier comprising a primary cathode, a collector electrode, and a plurality of secondary cathodes mounted successively and in staggered relation between said primary cathode and said collector electrode, each of said secondary cathodes having an intermediate portion and opposite end portions, one of which extends toward the next preceding electrode and the other of which extends toward the next succeeding

electrode, said end portions extending at equal angles from the intermediate portion and being substantially identical.

7. An electron multiplier comprising a primary cathode, a collector electrode spaced from said cathode, a plurality of secondary cathodes successively mounted between said primary cathode and said collector electrode, and a pair of field electrodes in operative relation with said collector electrode, one of said field electrodes being in juxtaposition to the face of the last secondary cathode toward said collector electrode and the other of said field electrodes being opposite the face of said collector electrode remote from said last secondary cathode.

8. An electron multiplier comprising a primary cathode, a plurality of secondary cathodes and a collector electrode mounted in successive arrangement, an auxiliary electrode disposed opposite the face of the last secondary cathode facing said collector electrode, and a second auxiliary electrode adjacent the face of said collector electrode remote from said last secondary cathode and extending between said remote face and the

secondary cathode next preceding said last secondary cathode.

9. An electron multiplier comprising a primary cathode, a collector electrode, a secondary cathode opposite said collector electrode, a second secondary cathode located between said primary cathode and said first secondary cathode, an auxiliary rod electrode adjacent the face of said first secondary cathode toward said collector electrode, and a plate auxiliary electrode adjacent the face of said collector electrode remote from said first secondary cathode, and extending toward said second secondary cathode.

10. An electron multiplier in accordance with claim 9 wherein said auxiliary electrodes are electrically integral.

11. An electron multiplier comprising a primary cathode, a collector electrode, and a pair of rows of secondary cathodes between said primary cathode and said collector electrode, the secondary cathodes in each row having electron emissive surfaces facing the other row, and each secondary cathode having substantially planar portions at opposite ends inclined toward the other row.

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