

March 5, 1940.

G. A. MORTON ET AL

2,192,579

ELECTRIC DISCHARGE DEVICE

Filed Feb. 27, 1937

2 Sheets-Sheet 1

FIG. 1.

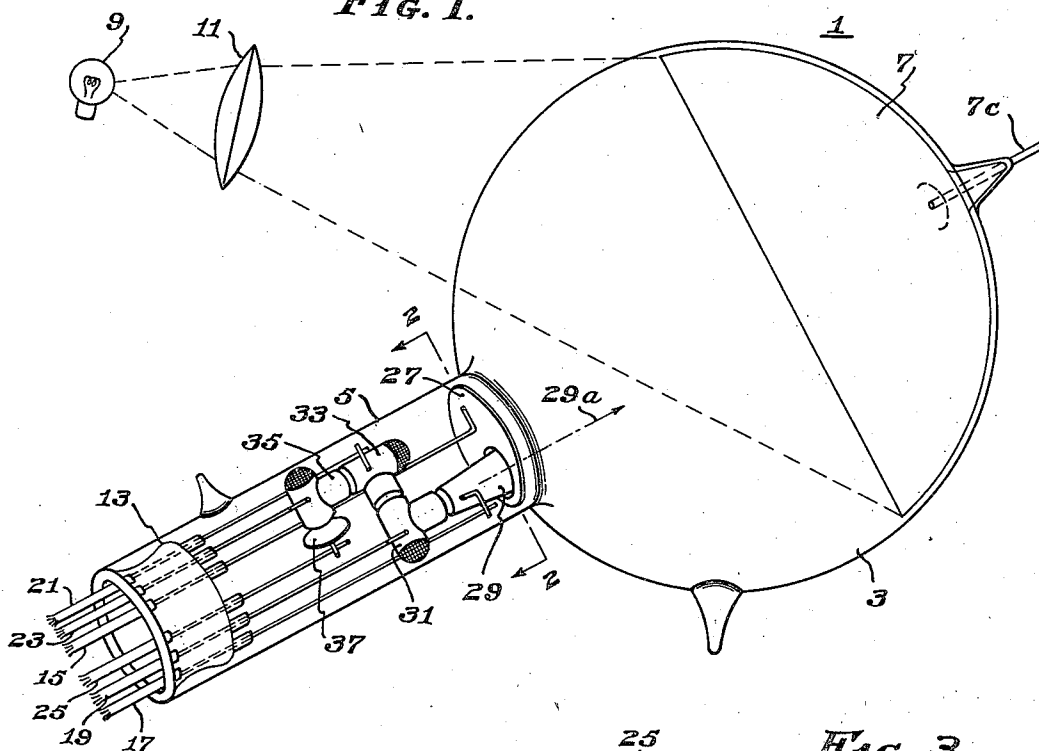


FIG. 2.

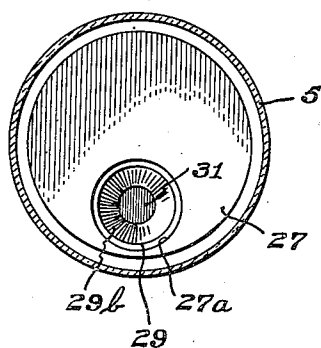
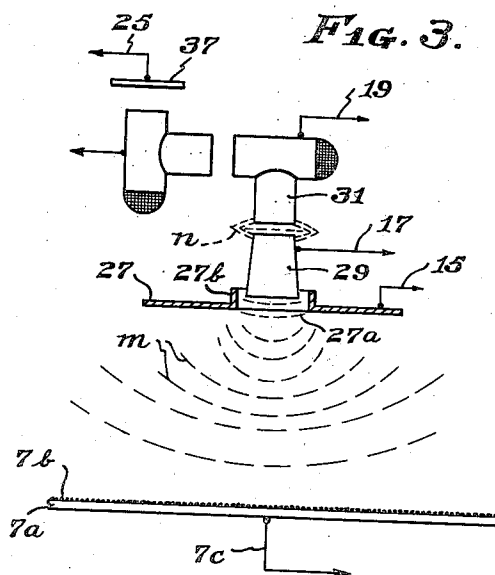


FIG. 3.



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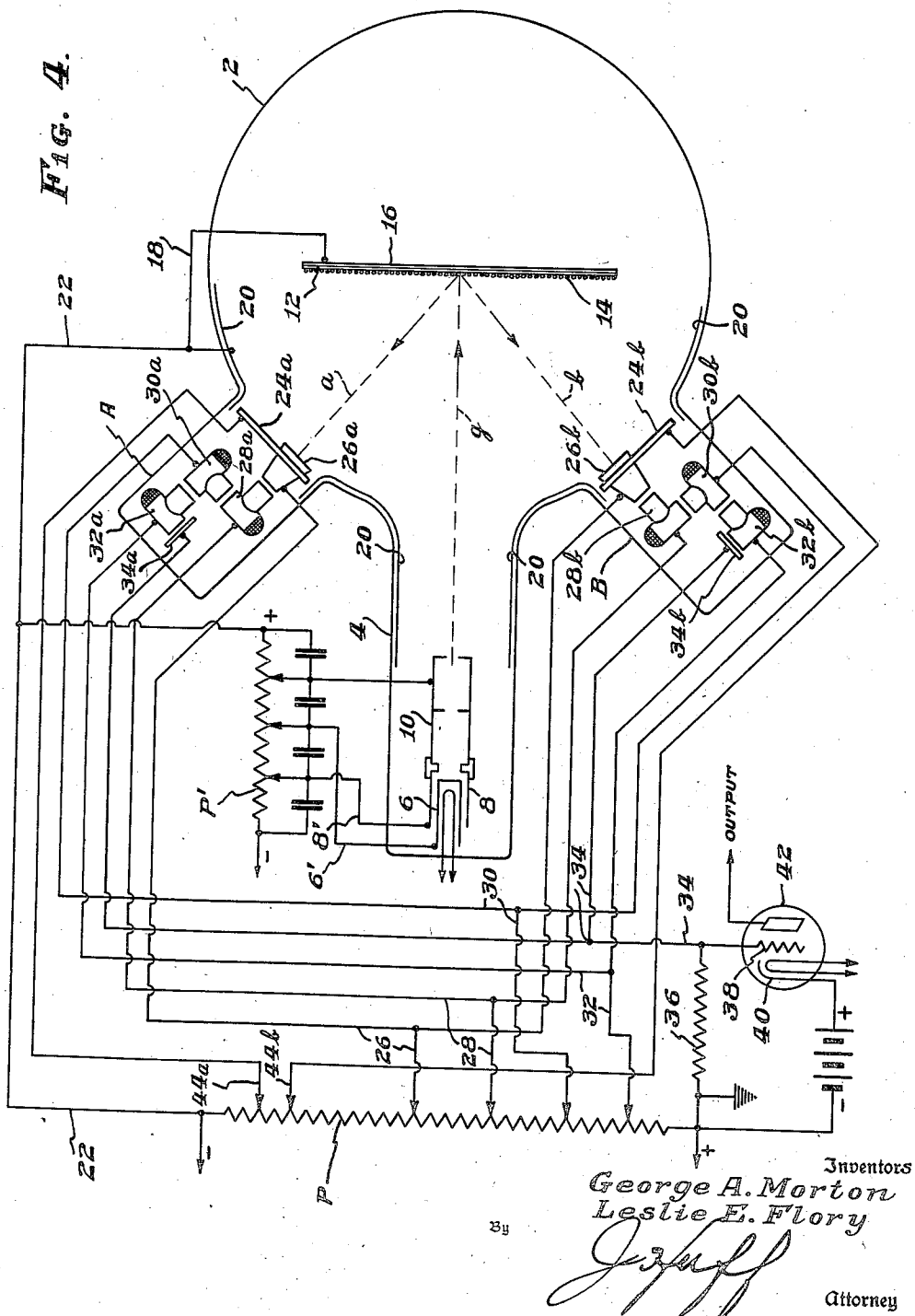
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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,192,579

ELECTRIC DISCHARGE DEVICE

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Application February 27, 1937, Serial No. 128,050

11 Claims. (Cl. 250—150)

Our invention relates to electric discharge devices, and particularly to devices of the type wherein amplification of a primary electron stream, such, for example, as is emitted from a thermionic cathode, or from a sensitized surface exposed to light, or to an electron beam, is accomplished through utilization of the phenomenon of secondary emission.

In order to obviate "shot effect", thermoagitation in the coupling devices, and other causes of noise incident to the use of separate amplifier tubes, it has heretofore been proposed to combine, in a single envelope, an electron multiplier with "special purpose devices" of various types. Thus, our copending application Serial No. 33,330, filed July 26, 1935, discloses a television tube of the type manufactured by RCA Manufacturing Company, Inc., under the trade-mark "Iconoscope", combined with a multi-stage electron multiplier. The multiplier is so positioned with respect to the mosaic (upon which the image to be televised is impressed) that electrons released therefrom by the scanning beam are drawn into the multiplier to therein give rise to secondary electrons which, in turn, are utilized for the production of further secondary electrons in as many electronic amplifying stages as may be necessary to achieve a desired power output.

In devices of the general character above described, it is preferable to make the multiplier as compact as is consistent with efficient operation, and to so mount it, as in a dependent neck portion of the envelope, that it will not interfere with the projection of the optical image, or light rays, upon the electrode constituting the source of the electrons to be multiplied. Where, as is usually the case, the entrance or "mouth" of the multiplier is of an area appreciably less than that of the area of the electrode constituting the primary electron source, difficulties arise in focusing the electrons from their source into the multiplier.

Accordingly, an object of our present invention is to provide a discharge device comprising a primary source of electrons and an electron multiplier, and having means incorporated therein for focusing or otherwise directing the electrons from said source to said multiplier.

Another object of our invention is to provide means for guiding electrons from a mosaic or other relatively large emissive surface into a multiplier in a manner to ensure efficient and uniform collection of the electrons from such surface.

Another object of our invention is to improve

the overall efficiency of electron discharge devices of the general character described.

The above and other objects are achieved in accordance with our invention by establishing the electrical equivalent of a series of condensing optical lenses of progressively decreasing focal lengths adjacent the area surrounding the entrance to the electron multiplier. Where, as in our earlier disclosure, the multiplier is mounted in a neck communicating with that portion of the vacuum envelope which contains the electron primary source, the lens elements may conveniently be constituted by an orificed metal disc positioned at the entrance to the neck, and by a truncated cone or funnel-shaped emissive electrode mounted with its wide end in line with the disc orifice. If the device contains a "second anode", this electrode may surround the disc, in which case the disc is preferably maintained a few volts positive with respect to it, and the funnel-shaped electrode is made two or three hundred volts positive with respect to the disc. With the electrodes so arranged and so energized, the equipotential surface constituting the electric field about the entrance to the multiplier will curve outwardly toward the electron primary source. These equipotential surfaces will have the smallest radii of curvature adjacent the orifice in the disc, whereby the electrons converge on the entrance to the funnel, through which they are drawn to succeeding multiplying stages.

Certain details of construction, together with other objects and advantages, will be apparent and the invention itself will be best understood by reference to the following specification and to the accompanying drawings, wherein:

Figure 1 is an illustration of a photo-electric device including an electron multiplier and having an electron lens, constructed in accordance with the principle of the invention, incorporated therein.

Fig. 2 is a plan view of the lens elements taken on the line 2—2 of Fig. 1;

Fig. 3 is a cross-sectional diagrammatic view of a slightly modified construction, illustrative of the approximate contour of the electric field about these elements when the device is in operation, and

Fig. 4 is a diagrammatic view of an "Iconoscope" including two electron multiplier devices each having an electron lens associated therewith and showing the connections of the various tube elements to potential sources during the operation of the device as a television transmitter.

The device of Fig. 1 is a photo-sensitive relay. Here, 1 designates generally an evacuated envelope comprising a bulbous portion 3 and a dependent neck portion 5. The vacuum space within the envelope 1 is continuous. A hemispherical surface 7, which may conveniently be of silver coated on the inner wall of the bulbous portion 3 of the tube, constitutes an electron primary source or cathode. As shown in Fig. 3 the cathode may alternatively be in the form of a plate 7^a treated with any of several materials 7^b adapted to release electrons in response to the impression thereon of rays (of any wave length) from an external source, exemplified in Fig. 1 by a lamp 9 and an optical lens 11. A lead 7^c, which extends through the wall of the tube, serves to connect this photo-sensitive cathode 7 to an external source of potential, not shown.

The neck portion 5 of the tube contains an electron multiplier, preferably of the electrostatic type, to which the electrons emanating from the cathode 7 are drawn (in a manner later described, to therein give rise to an augmented electron current of sufficient intensity and power to directly operate an output device without the interposition of separate amplifying tubes.

The extension or neck 5 terminates in a press 13, through which six leads, 15, 17, 19, 21, 23 and 25, pass. Lead 15 supports an orificed disc 27 adjacent the mouth of the extension or neck 5. The orifice 27^a in disc 27 may be provided with an inwardly extending rim 27^b, as shown in Fig. 3. It need not, however, be in the center of the disc as there indicated but may be off-set from the center as shown in Fig. 2. Lead 17 supports a truncated cone or funnel-shaped electron target or "collector" electrode 29, the wide end of which is presented to the orifice 27^a in disc 27 and terminates in a plane adjacent or substantially adjacent the plane of that surface of disc 27 which faces the electron primary source 7. The axis of symmetry 29^a, of the cone intercepts the surface of the cathode 7. In Fig. 3, the wide end of electrode 29 is shown as terminating within the space circumscribed by the rim 27^b on disc 27. The inner surface of this electron collecting electrode 29 is rendered secondarily emissive as by a coating 29^b (Fig. 2) of caesium or the like.

Leads 19, 21 and 23 support T-shaped hollow multiplying electrodes 31, 33 and 35, respectively. One open end of electrode 31 is presented to the inner end of the funnel-shaped electrode 29, and the other open end of electrode 31 is presented to the mouth of the next multiplying electrode 33. Similarly, the other end of electrode 33 is aligned with an opening in electrode 35, which latter electrode has its terminal hollow end presented to an output electrode 37 supported on lead 25. Each of the multiplying electrodes 31, 33 and 35 will be understood to have their inner surfaces treated, as with caesium, to enhance secondary emission. To facilitate such treatment during the construction of the device, parts of these electrodes may be of meshed construction as shown.

For the purpose of concentrating, accelerating and directing electrons from one multiplying electrode to the next multiplying electrode, an electron lens is disposed between adjacent hollow electrode terminals. These lenses are constituted respectively by the electrostatic field which is set up between the spaced terminals of the adjacent electrodes when appropriate positive potentials are applied therebetween.

The lens action with which our present invention is especially concerned is that which takes place between the electron primary source 7 and the entrance to the multiplier. Here the problem is to focus the electrons emitted from a large surface upon a remote smaller area, i. e. upon the area circumscribed by the wide end of the frustro-conical electrode 29. This problem is quite different from that obtaining, for example, between the adjacent ends of members 29 and 31 where the focusing action may be simply achieved, in agreement with a known formula, by establishing the electrical equivalent of a bio-convex optical lens, as indicated at *n*, Fig. 3. Considered from one aspect, therefore, our present invention is predicated upon the discovery that the problem involved in focusing electrons from a relatively large surface upon a remote smaller surface may be solved by the provision of an electron-lens system intermediate these surfaces which is the substantial electrical equivalent of a series of condensing optical lenses of progressively diminishing focal length. The invention further resides in the design, position and arrangement of the lens elements and of the relative potential distribution required to achieve the desired electron focusing action.

Referring now to Fig. 3 wherein like reference characters represent the same parts or parts similar to those described in connection with Fig. 1. The exact potential applied to the accelerating electrode 27 will be dependent at least to some extent upon its distance from the electron primary source 7. Ordinarily it will be maintained a few volts positive or a few volts negative with respect to the electron primary source 7^b. The potential applied to the frustro-conical electrode 29 should preferably be a few hundred volts positive with respect to the potential applied to electrode 27. When so operated the contour of the equipotential surfaces constituting the electrons lens will be substantially that indicated by the dotted lines "m". Electrons entering this field will be drawn over into the funnel and the majority of them will pass therethrough without striking its emissive walls. The electrons which do strike the walls of electrode 29 will release secondary electrons which, like the non-impinging electrons, are drawn inwardly to the next emissive electrode 31. The electrons which arrive at electrode 31 directly from the cathode 7 will be traveling at a higher velocity than the secondary electrons released from the inner surface of the funnel. A greater signal to noise ratio is obtained with the high speed electrons from the cathode 7 (by reason of the greater secondary emission ratio) than is obtained with the lower speed electrons from the emissive surface of the funnel 29. Accordingly, optimum performance is achieved when the focusing action adjacent the entrance to the multiplier is such as to cause substantially all of the electrons to pass through the funnel without striking it. This focusing action may be regulated by adjusting the potentials, applied through leads 15 and 17, to electrodes 27 and 29, respectively.

Fig. 4 shows the invention as applied to a television transmitting tube of the type disclosed in our copending application Serial No. 122,690, filed January 28, 1937. In this drawing 2 designates a bulbous evacuated container which has an elongated neck portion 4 wherein an electron source of the type commonly designated as an "electron gun" is mounted. The electron gun 75

comprises a thermionic cathode 6, surrounded by a grid element 8 coaxial therewith and includes a cylindrical first anode 10 coaxial with the grid element. The specific construction of the gun forms no part of our invention and it is now so well known to those skilled in the art as to need no further explanation.

A cathode or target, of the mosaic type, is mounted in the bulbous portion of the container and is so oriented with respect to the electron gun as to be accessible to the electron stream, or cathode ray during the scanning operation. The target is constituted by a sheet of insulating material 12 such as mica, the surface of which, exposed to the electron stream, carries a large number of minute discrete photo-sensitive metallic particles 14. The mica sheet, in turn, is supported from a metallic back-plate 16 which is provided with a lead 18 that extends through a wall of the tube to the exterior thereof. Since the emissive surface 14 is electrically insulated, by the mica sheet 12, from the metallic back-plate 16 this electrode may be said to have "zero transverse conductance."

The inner surface of the neck portion of the container, adjacent to the end of the first anode, is provided with a metallic coating 20 to which is connected an exteriorly extending conductor 22. The coating has the double function of focusing the cathode ray to a fine spot upon the target and of accelerating photo and secondary electrons away from the photosensitive globules during the scanning operation. The metallic coating may also extend over the whole inner surface of the bulb, with the exception of an area sufficiently large to permit focusing of an optical image on the target. The more extensive coating, if utilized, prevents the walls of the tube from acquiring charges and gives rise to optimum field-conditions.

Attention is also directed to the fact that, in order to simplify the drawings, the ray deflecting coils, usually four in number, one pair of horizontal and one pair for vertical deflection, are omitted.

During the utilization of the device to transmit or televise a scene, an optical image of the scene is focused sharply upon the surface of the target carrying the photosensitive particles. The light causes emission from the particles 14 of photo-electrons which are accelerated, in the return direction, toward the conductive coating 20. It is our belief that, as a result of the emission of photo-electrons, each minute globule acquires a charge proportional to the light intensity of the elemental area of the optical image that is focused upon it. During the scanning operation, as each globule is struck by the beam, its charge is neutralized and, at the same time, secondary electrons are emitted from the globules, their number varying in proportion to the neutralized charge.

In order to make use of the secondary electrons, (rather than the changes in the electrical condition of the device occasioned by the successive neutralizing of the minute charges acquired by the particles) we connect to the container two or more electron-multiplier devices in such manner that the vacuous spaces of the main cathode ray tube and of the multipliers are continuous. In the illustrated embodiment of our invention, but two multipliers are employed, they are mounted within the vacuous extensions A and B of the main body of the container. The axes a , b of the entrances through which the electrons

enter the multipliers form an angle of substantially 40° to a plane normal to the center of the mosaic. These axes and the normal preferably lie in a common plane. This plane is at a right angle to the plane defined by the normal and the axis g of the electron gun.

The precise angles (with respect to the normal of the mosaic) at which the electron-multipliers are disposed is not critical. The lower limit of the permissible range of angles is determined by the necessary presence of the window through which the optical image is impressed upon the mosaic. Ordinarily, the electron multipliers will be so disposed that their axes will form angles of from 30° to 50° with the normal, though they may be mounted up to substantially 90° without rendering the device inoperative. It is preferable to mount the multipliers symmetrically about the normal, through this is not essential since it is the combined or average output of all of the multipliers that is utilized.

In the operation of our improved device it is preferable to connect duplicate electrodes (other than the discs, here designated 24^a , 24^b) of the separate multipliers in parallel and to so supply potentials to the various electrodes that a potential gradient exists between the parallel connected output electrodes 34^a , 34^b and the electron emissive cathode 6 of the cathode ray tube per se.

Such potentials may be supplied from any well regulated direct current potential source, as exemplified by a potential divider P, P' to the negative end of which the grid or control element 8 of the cathode ray tube is connected and to the positive end of which the common lead 34 of the output electrodes of the multipliers is connected over a circuit including an impedance device 36 connected between the grid 38 and cathode 40 of an output amplifier tube 42. From an inspection of Fig. 4 it will be noted that the cathode 6 of the transmitting tube is variably connected by lead 6' to the potential source P' at a point more positive than the connection 8' to the source of the grid or control element 8. Such variable connection is for the purpose of properly adjusting the static bias on the transmitting tube to the best operating point.

It is also to be understood that the common leads to 26, 28, 30 and 32, inclusive, for the similarly numbered multiplying electrodes may be connected, respectively, to points upon the potential source successively more positive than the connection thereto of the grid or control element in the cathode ray tube. The separate leads 44^a and 44^b from the disc elements 24^a and 24^b , respectively, are variably connected to source P at points intermediate the points to which lead 22 from the second anode 18 and lead 26 from the funnel shaped collecting elements 26^a , 26^b are connected.

When an optical image is focused upon the layer of particles in the transmitting tube each particle, according to our present understanding, emits photo-electrons which leave the illuminated particles thus causing the said particles to acquire charges, respectively, that are proportional to the light intensity of the elemental areas of the optical image. During the scanning operation, whereby a cathode ray or beam of electrons is caused to repeatedly traverse the photo-sensitized surface in two directions simultaneously, the charges are sequentially released and at the same time secondary electrons are emitted in an amount varying in proportion to the neutralized

charges. According to our present understanding of the manner in which our improved device functions the secondary electrons are drawn over into the separate multipliers by reason of the previously described electron-lens which is established in front of the discs 24^a, 24^b and funnel-shaped collecting electrodes 26^a, 26^b which are each maintained at potentials which are high relative to the potential of the second anode 20.

10 The potential on each funnel-shaped electrode is higher than the potentials of the discs 24^a, 24^b so that substantially all of the electrons from the mosaic enter these electrodes 26^a, 26^b where they may strike the emissive walls to release additional secondary electrons which, together with the non-impinging electrons, are accelerated towards and enter the first T-shaped multiplying electrodes 28^a, 28^b by reason of the higher positive potentials applied thereto. The electrostatic field existing between the adjacent edges of electrodes 26^a, 28^a and 26^b, 28^b constitute electron lenses which focus and direct the electrons in their passage therebetween.

The impact electrons emitted by the first T-shaped multiplying electrodes 28^a, 28^b are directed and focused upon the next multiplying electrodes 30^a, 30^b by reason of a similar electrostatic field existing therebetween. Upon reaching the second T-shaped multiplying electrodes 30^a, 30^b the secondary electrons, in turn, drive out further secondary electrons which are similarly focused and drawn to the next multiplying electrodes 32^a, 32^b from whence they are drawn over to the output electrodes 34^a, 34^b and give rise to a fluctuating current in the output resistor 36 that is a greatly amplified replica of the electron currents which enter the multipliers from the transmitting tube.

As previously set forth the leads 44^a, 44^b, to the disc-shaped accelerating electrodes 24^a, 24^b are preferably separately connected to the source P. This permits of control of the quantity of secondary-electrons, from the mosaic, entering the separate multipliers whereby complete control of picture shading and background is achieved.

Thus, should the surface of the mosaic be unevenly activated during manufacture, or should it or the multipliers be misaligned with the result that more electrons would ordinarily enter one multiplier than the other, such inequalities may be compensated for by altering the potential applied to one or another of the discs, whereby the electrons from the mosaic are equally distributed among the several multipliers. Again, should it be desirable to shade a portion of the televised image in a manner other than that dictated by the shading of the optical image, the potentials on the discs may be separately varied to increase the quantity of electrons entering that multiplier on the side of the mosaic containing that portion of the image which is to be intensified.

Obviously, the number of separate multipliers employed may be greater than two, the maximum number being limited only by the physical dimensions of the tube and by the mechanical difficulties incident to connecting a large number of multipliers to the tube without obstructing the window through which the optical image enters the device. Further, we may employ as many multiplying stages in the separate multipliers as are desirable.

Where more than one electron-multiplier is employed the contour of the equipotential sur-

faces constituting the electron lens in front of the multipliers may be somewhat more complex than that illustrated in connecting with Fig. 3, due to "overlapping" of the several electrostatic fields. It is to be understood, therefore, that our invention is not to be limited to means for achieving the specific type of field illustrated.

We are aware of other physical modifications of our device and many other possible uses therefor that at once will be apparent to those skilled in the art. Our invention, therefore, is not to be limited except insofar as is necessitated by the prior art and by the spirit of the appended claims.

What is claimed is:

1. An electric discharge device comprising an evacuated envelope containing a surface constituting an electron primary source, a collector electrode mounted remote from said surface and having an area less than that of said surface, and electrode means for establishing a condensing electron-lens intermediate said emissive surface and collector electrode, whereby to converge the electrons from said emissive surface upon said smaller collector electrode.

2. An electric discharge device comprising an evacuated envelope containing a surface constituting an electron primary source, a collector electrode mounted remote from said surface and having an area less than that of said surface, and means including said collector electrode for establishing a condensing electron-lens intermediate said emissive surface and collector electrode, whereby to converge the electrons from said emissive surface upon said smaller collector electrode.

3. An electric discharge device comprising an evacuated envelope containing an electron primary source, a collector electrode mounted remote from said surface and having an area less than that of said surface, and electrode means for establishing the electrical equivalent of a series of condensing optical lenses of progressively decreasing focal lengths intermediate said source and collector, whereby to converge the electrons from said emissive surface upon said smaller collector electrode.

4. The invention as set forth in claim 3 wherein said electron primary source is constituted by an electrode of the type having zero transverse conductance.

5. The invention as set forth in claim 3 wherein said collector electrode is provided with a secondary-electron emitting surface.

6. An electric discharge device comprising an evacuated envelope in which are mounted an electron emissive surface and an electron-multiplier, said multiplier including a collector electrode accessible to electrons from said surface, said collector electrode having an area less than that of said emissive surface, and an accelerating electrode mounted adjacent said collector electrode, said collector and accelerating electrodes constituting elements of a converging electron-lens for concentrating the electrons from said emissive surface upon said smaller collector electrode.

7. An electric discharge device comprising an evacuated envelope in which are mounted an electron emissive surface and an electron multiplier, said multiplier including a collector electrode having an area less than that of said surface and an axis which intercepts said surface, and an accelerating electrode mounted in a plane normal to said axis, said collector and accelerat-

ing electrodes constituting elements of a converging electron-lens for concentrating the electrons from said emissive surface upon said smaller collector electrode.

5 8. The invention as set forth in claim 7, wherein said accelerating electrode comprises a metal surface having an orifice therein and said collector electrode comprises a hollow cylindrical member having an end presented to said orifice.

10 9. The invention as set forth in claim 7, wherein said accelerating electrode comprises a metal surface having an orifice therein and said collector electrode comprises a funnel-shaped member having its wide end presented to said orifice.

15 10. The invention as set forth in claim 7,

wherein said collector electrode has a secondary-electron emitting surface.

11. An electric discharge device comprising an evacuated envelope in which is mounted an electron gun, a target electrode adapted to release 5 secondary electrons in response to the impact thereon of electrons from said gun, a collector electrode mounted on the gun side of said target but remote from said gun for collecting secondary 10 electrons from said target, means for focusing electrons from said gun upon said target and means for focusing secondary electrons from said target upon said collector electrode.

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