

July 20, 1943.

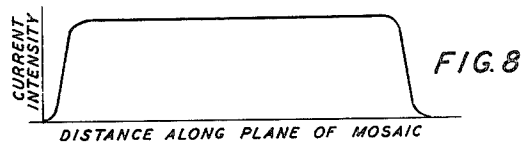
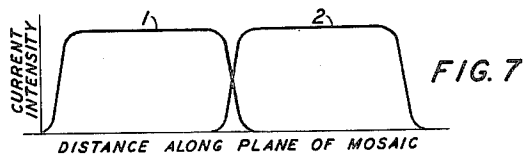
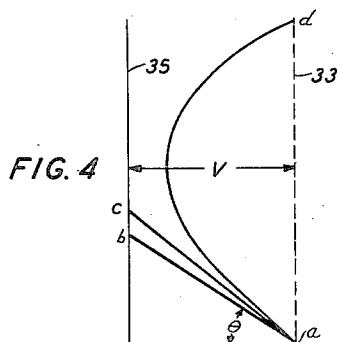
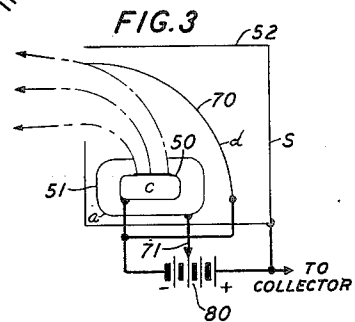
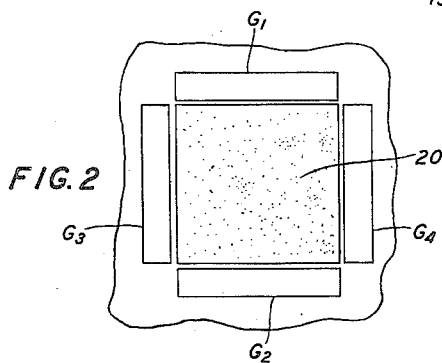
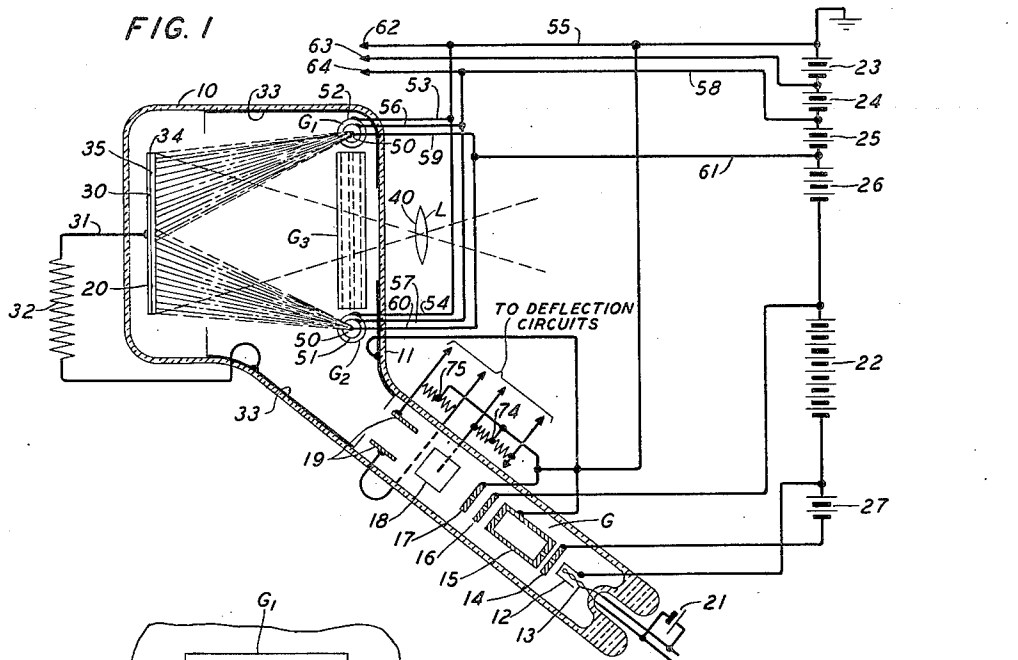
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2,324,534

TELEVISION TRANSMITTER

Filed Sept. 30, 1941

2 Sheets-Sheet 1



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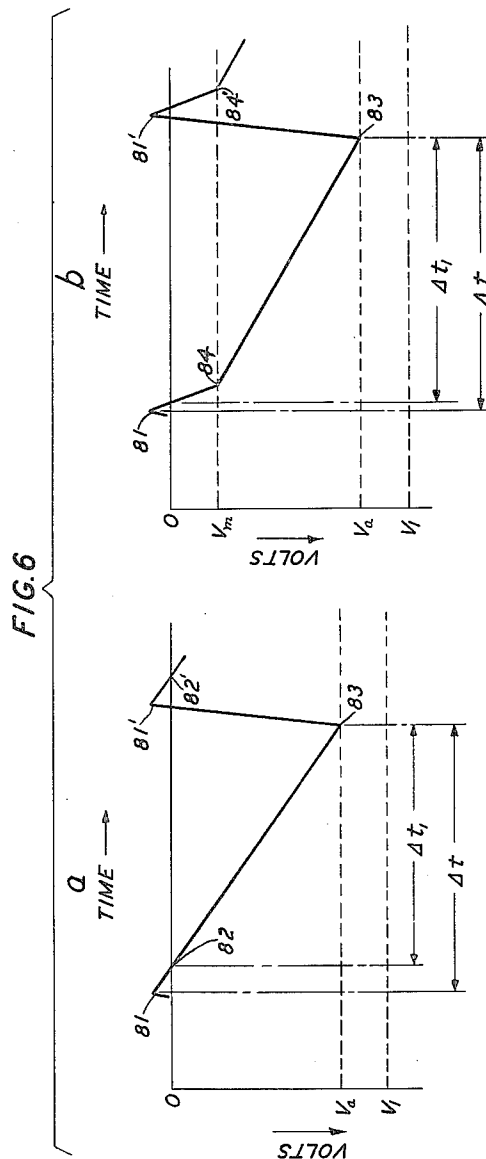
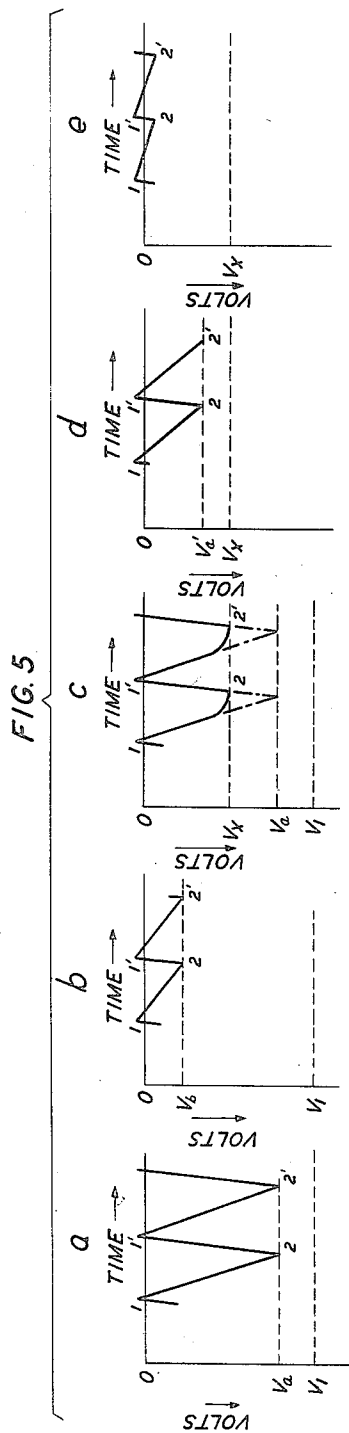
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2,324,534

TELEVISION TRANSMITTER

Filed Sept. 30, 1941

2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,324,534

TELEVISION TRANSMITTER

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Application September 30, 1941, Serial No. 412,937

18 Claims. (Cl. 178—7.2)

This invention relates to electron discharge devices and more specifically to electron camera tubes for television and to methods of operating tubes of this type.

There has already been devised a television camera tube of the type in which an image of the picture to be transmitted is formed upon a mosaic of minute light-sensitive elements supported on and insulated from a common metallic back-plate. Each element is the cathode of a photoelectric film, a collecting electrode within the tube common to these elements forming a common anode for the array of small cathodes. Each of the photoelectric cell cathodes acquires a potential, as electrons are emitted therefrom to the collecting electrode, which has a value depending upon the intensity of the light striking it. The mosaic is scanned by a cathode ray beam whereby picture current appears in an output circuit, the picture current having a value depending on said potentials of the light-sensitive elements. The sensitivity of this cathode ray tube is improved by applying a negative polarizing voltage to the light-sensitive elements by providing the tube with an auxiliary source of electrons and spraying these electrons upon the light-sensitive mosaic. The electrons are projected towards the mosaic at a comparatively low velocity, that is, lower than the velocity corresponding to some potential V_0 at which one electron striking the mosaic surface will on the average cause less than one electron to leave the surface. The value of V_0 is dependent upon the specific material used in the mosaic; for the usual cesiated surfaces V_0 is of the order of 10 to 20 volts, but in some cases it may be as high as 65 volts or more. A stream of such low velocity electrons with an energy less than V_0 striking the mosaic surface will result in an accumulation of electrons on the surface and a lowering of potential of the surface. Electrons may be sprayed upon the mosaic continuously or may be applied intermittently, as at the end of each horizontal scanning line. Such a camera tube is disclosed in Patent 2,147,760, issued February 21, 1939, to Vance et al.

In accordance with the present invention, which is an outgrowth of an investigation of camera tubes of the type above described, there is provided a tube in which the low velocity electrons produce a greatly increased reduction of the potential of the target, thus materially increasing the sensitivity obtainable in this type of tube.

In an arrangement of the type described

above, as the electrons from the auxiliary gun strike an elemental region of the mosaic, the potential of that region will be lowered gradually. It is obvious, from the law of conservation of energy, that the potential of the region cannot become lower than the potential of the cathode of the auxiliary gun, which is at a potential V_1 with respect to the potential of the final anode in the primary electron gun (the collecting electrode, generally) and also with respect to the final anode of the auxiliary gun. However, if the electrons are projected towards the mosaic at a considerable angle to the normal to the mosaic, the lowest negative potential the mosaic can attain with respect to the final anode potential is considerably less than V_1 , or in other words, the effectiveness of the low velocity electrons is lowered. Just how low a potential can be attained depends on the angle of projection and on the exact nature of the field between the mosaic and the collecting electrode (the final anode of the primary gun). It has been found that, for the case where there is a uniform field between the mosaic and the collector electrode, electrons cannot strike the mosaic if it is at a lower potential with respect to the collecting anode than $V_1 \cos^2 \theta$, where θ is the angle that the electron beam from the auxiliary electrode makes with the normal to the surface of the mosaic. Considerable departure from exact uniformity of the field may be present without much change in this relationship. In the Vance et al. arrangement, the electrons strike the center of the mosaic from a low velocity gun at an angle, θ , which appears to be approximately 52 degrees, so that $\cos^2 \theta$ is approximately 0.37 while for electrons striking the mosaic, near the remote edge, θ is approximately 60 degrees and $\cos^2 \theta$ approximately 0.23. As explained above, it has been found that this places an unnecessary limit upon the negative potential which can be given to the mosaic. Moreover, because of the angle of approach of the auxiliary electrons a shift in the position of the low velocity beam occurs during operation which is likely to produce spurious effects in the signal. This is further discussed below.

On object of this invention is to provide an improved method of operating an electron discharge device to largely, at least, overcome the above-mentioned disadvantage.

It is also an object of this invention to provide an improved electron discharge device which overcomes, at least in large degree, the above-mentioned disadvantages.

Another object of the invention is to provide a plurality of cooperating electron guns for spraying electrons over a target to impart to it a substantially uniform low potential.

In the present invention, means are provided for spraying electrons upon the target from an auxiliary low velocity source at such an angle that $\cos^2 \theta$ does not differ greatly from unity. By way of example, for an angle with respect to the normal of $\theta=15$ degrees, $\cos^2 \theta=0.93$ and the negative potential imparted to the mosaic is only 7 per cent less than that produced when $\cos^2 \theta$ is unity.

In accordance with an illustrative embodiment of the present invention, there is provided an electron discharge device having a mosaic target upon which an optical image is projected, means for scanning the mosaic with a beam of primary electrons, and a plurality of supplementary electron guns for generating beams of such low velocity that the secondary emitting ratio of the material for that velocity is less than 1. These supplementary guns are so disposed that a large portion, at least, of the electrons therefrom reach the mosaic target as nearly as possible normal to the plane of its front face. The guns are preferably made so that they produce an electron beam which has a considerable extent in one direction; for example, the beam when it strikes the target may have a dimension in one coordinate direction corresponding to the width of the target but have a dimension in the other coordinate direction of approximately one half of the mosaic dimension in this direction. Each supplementary electron gun thus forms a wedge-shaped beam which resembles somewhat the partially opened leaves of a book. With this type of gun, electrons obviously reach various portions of the mosaic more nearly normal to the surface than is the case with a gun giving a conical beam. Moreover, this solves the problem of proper overlapping of beams which is raised with the use of two or more guns.

While two, four, six or any number of auxiliary guns may be used, there has been shown, by way of example for purposes of illustration, an arrangement in which four low velocity guns are disposed within the container so that their beams are directed upon the mosaic target in such a manner that the axes of said beams are, as nearly as possible, normal to its surface. Two of the guns may have the long dimension of their beams parallel to one dimension of the mosaic as, for example, the height, while the other two guns may have the long dimensions of their beams parallel to the other dimension of the mosaic as, for example, the width. In one form of this arrangement, two of the guns generate an abundance of very low velocity electrons, while the other two generate a smaller current of fairly low velocity electrons, but not as low as the very low velocity electrons. By way of example, the very low velocity electrons may be from 1 to 5 volts while the fairly low velocity electrons may be of from 10 to 20 volts. The very low velocity electrons bring the mosaic to a potential which is negative with respect to the collecting electrodes a very short time after scanning. As the mosaic elements gradually become more negative, the electrons from this gun no longer reach the mosaic and have no further effect. The current from the fairly low velocity electron beam generating means, however, although smaller in intensity, acts at all times. The cathodes of the auxiliary guns may be hid

from the mosaic by novel electron gun construction so that the material of the cathodes cannot evaporate onto the mosaic.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof in which:

Fig. 1 is a schematic view of a television transmitter system in accordance with the invention;

Fig. 2 is a partial side elevation view of the tube shown in Fig. 1 with portions thereof broken away;

Fig. 3 is a somewhat larger view of a supplementary electron gun which may be used in the tube shown in Fig. 1; and

Figs. 4 to 8, inclusive, are graphical and diagrammatic representations to aid in explaining the invention and the operation thereof.

Referring more specifically to the drawings, there is provided, by way of example to illustrate the principles of this invention, a television transmitting system employing an electron discharge device 10 together with certain of its associated circuits. The tube 10 preferably comprises a highly evacuated envelope 11 enclosing a primary electron gun G consisting of a cathode 12, a cathode heater 13, a modulating electrode 14, a first anode 15, a second anode 16, and a third anode 17, two pairs of electrostatic deflecting plates 18, 18 and 19, 19, a final anode 33 (the collecting electrode) which is preferably in the form of a conducting coating on a portion of the walls of the tube, a mosaic target 20, and a plurality of supplementary electron guns G₁, G₂, G₃ and G₄ for generating and projecting upon the target low velocity electrons.

Referring first to the primary gun G, current for the heater 13 is supplied by a source of potential 21. The cathode 12 is connected to the negative terminal of a source 22, the positive terminal of which is preferably connected to the second anode 16. The first and third anode members 15 and 17 and the final anode member 33 are connected to the positive terminal of a source 23 which positive terminal is preferably connected to ground. The negative terminal of source 23 is connected through the sources 24, 25 and 26 to the positive terminal of the source 22. The negative terminal of the source 22 is connected to the positive terminal of the source 27, the negative terminal of which is connected to the modulating electrode 14. While separate sources have been shown for convenience, it is obvious that the sources 22 to 27, inclusive, may be a single source, such as a potentiometer resistor the terminals of which are connected to any suitable source of direct current, such as a rectifier or battery. By means of this arrangement, the highest potential of the tube is ground potential, which is that of the anode members 15, 17 and 33. This potential is from 1000 to 2000 volts positive with respect to cathode potential which is thus 1000 to 2000 volts negative with respect to ground. The modulating or control electrode 14 is placed at a potential which is negative with respect to the cathode. The potential of the electrode 16 is somewhere between the potential of the cathode and the potential of the electrode members 15 and 17 and is adjusted to give the desired current. The exact potentials of the various electrode members are chosen in accordance with well-known electron lens practice so that the beam of electrons is brought to a sharp focus at the mosaic target 20. The mosaic target 20, which per se is not part

of the present invention, may be constructed in a variety of ways. In a preferred form it consists of a thin sheet of mica or glass 34 having a continuous metallic coating 30 on the back thereof which is connected by means of the lead 31 to an output resistor 32, the other terminal of which coating is connected to the conducting coating 33 in the tube. The metallic coating 30 will be referred to as the signal plate. The mosaic proper may consist of a multitude of silver globules 35 each of which has a film of silver oxide thereon, the silver oxide film being coated with caesium. In such a mosaic, the light-sensitive elements are electrically insulated from each other and from the metallic coating or signal plate 30 on the back of the mica or glass sheet 34. Another possible method of constructing a suitable mosaic is that of forming a light-sensitive layer upon the front side of the mica and separating the light-sensitive material 35 into a large number of elements insulated from each other by ruling the light-sensitive film with a ruling machine. Still another suitable method of making the target is to form an exceedingly thin coating of light-sensitive material upon the glass or mica, the coating not necessarily being discontinuous, but being so thin that the resistance between picture elements is very high.

In order to cause the electron beam, formed by the electron gun apparatus described above, to scan every elemental area of the image or field of view on the mosaic target 20 in turn, suitable deflecting means such as, for example, two pairs of deflecting plates 18, 18 and 19, 19, the axes of which are located at right angles to each other, are provided. To the deflecting plates 18, 19 are applied deflecting voltages of framing frequency and having a saw-tooth wave form to produce the vertical deflection of the beam while deflecting voltages of line scanning frequency and of saw-tooth wave form are applied to the deflecting plates 18, 18 to produce the horizontal deflection of the beam. Any suitable sweep circuits (not shown), may be used to generate these horizontal and vertical deflecting voltages. For example, Patent 2,178,464, issued October 31, 1939, to M. W. Baldwin, Jr., discloses appropriate balanced sweep circuits for this purpose. Connections may be made from the balanced sweep circuits to the pairs of plates 18, 18 and 19, 19 by means of high resistance coupling resistors 74 and 75, respectively connected across the pairs of plates 18, 18 and 19, 19. The mid-points of the resistors 74 and 75 are connected to ground in order that the average potential of the deflecting plates is at all times substantially equal to the potential of the final anode which, in the arrangement shown, is the potential of the electrodes 15, 17 and 33. For a full description of the advantages of balanced sweep circuits, reference may be made to the above-mentioned Baldwin patent and also to Patent 2,209,199, issued July 23, 1940, to Frank Gray.

Outside the cathode ray tube 10 is an optical system represented generally by the single lens 40 for projecting an image of an object upon the photosensitive surface 35 of the mosaic target 20. The tube 10 is so arranged that the axis of the radiations striking the target 20 from the object or field of view is substantially normal to the surface of the mosaic, as will be pointed out more fully below.

Also arranged within the container 11 are four auxiliary electron guns G_1 , G_2 , G_3 and G_4 . As shown in Fig. 2 which is a side elevational view

of a portion of the tube shown in Fig. 1 with parts of the walls of the envelope 11 broken away to show the interior of the tube, the four guns G_1 , G_2 , G_3 and G_4 are arranged so that they are not in the path of the light from the object. These guns are preferably of a type to produce a long wedge-shaped beam. The four auxiliary guns generate beams of low velocity, that is, not exceeding 20 volts and may be grouped into a first group comprising, for example, the guns G_1 and G_2 , which are used to spray a small quantity of 10 to 20 volt electrons upon the mosaic target 20 and a second group, comprising the auxiliary guns G_3 and G_4 , for spraying a large quantity of from 1 to 5 volt electrons upon the mosaic target 20. The reason for this grouping will be considered below.

Before describing the details of suitable auxiliary guns G_1 to G_4 , inclusive, it seems advisable to discuss the considerations which led to the present invention. First of all, it should be understood that an electron striking the mosaic surface with an energy lower than that corresponding to some potential V_0 will on the average cause less than one electron to leave the surface. On the basis of experience with cesiated surfaces, V_0 is usually of the order of 10 or 20 volts, although several experimenters suggest that V_0 may have a value as high as 65 volts. It will be apparent, however, that the scope of the invention is not limited to an exact value of V_0 .

A stream of such electrons with an energy less than V_0 , striking the mosaic surface 20, will thus tend to result in an accumulation of electrons on the surface and a lowering of potential of the surface. On the other hand an electron striking the surface with an energy somewhat greater than that corresponding to the potential V_0 will on the average cause the emission of more than one electron. Reference will now be made to Fig. 3 which shows one type of low velocity auxiliary electron gun which may be used in this invention, although it is to be understood that the invention is not limited to any particular type of auxiliary electron gun, the arrangement in Fig. 3 being merely a preferred form. The low velocity gun shown in this figure comprises a cathode 50 which is preferably a long strip, a first accelerating anode 51 and a final accelerating electrode 52. A deflecting electrode 70, which is curved so that the electrons are caused to be deflected in such a manner that the axis of the deflected electrons is approximately at right angles to the plane of the emitting surface of the strip cathode 50, is connected at cathode potential and is placed between the anode members 51 and 52. In the arrangement shown in Fig. 1, the final accelerating anodes 52 of all four guns G_1 , G_2 , G_3 and G_4 are preferably connected to ground by means of the connections 53, 54 and 55. The first accelerating electrodes 51 of the tubes G_1 and G_2 are connected by means of the leads 56, 57 and 58 to the common terminal of the sources 24 and 25. The cathodes 50 of the tubes G_1 and G_2 are preferably connected through connections 59, 60 and 61 to the common terminal of the sources 25 and 26 which places each cathode at a potential of from 10 to 20 volts negative with respect to the potential of the final accelerating electrode 52, or in other words, the final electrode 52 is from 10 to 20 volts positive with respect to the potential of the cathode. The leads 62, 63 and 64 are connected to the final accelerating electrodes 52, the first accel-

erating electrode 51 and the cathode, respectively, of the auxiliary guns G₃ and G₄ which are similar to the guns G₁ and G₂. By this means a positive potential of from 1 to 5 volts with respect to the potential of the cathode is placed upon the final accelerating electrodes 52 of these two guns G₃ and G₄ inasmuch as the lead 64 is connected to the common terminal of the sources 24 and 25 while the lead 62 is connected to ground. The lead 63 is connected to the common terminal of sources 23 and 24 and thus is placed at a potential which is intermediate ground potential and the potential of the lead 63, thus making the potential of the first accelerating member 51 of the guns G₃ and G₄ intermediate that of the cathode 50 and the final accelerating electrode 52. While it is not absolutely necessary that the potential of each member 51 be intermediate that of each of members 50 and 52, this is the more usual arrangement.

The four guns G₁, G₂, G₃ and G₄ are preferably arranged symmetrically about the normal to the mosaic through the center of the scanning field thereon. The currents of the auxiliary guns are controlled by varying the potentials of the intermediate electrodes 51 with respect to the potentials of the cathodes 50 as indicated schematically in Fig. 3 which shows the cathode 50 of the gun in that figure connected to the negative terminal of a source 80 and the potential of the final electrode 52 connected to the positive terminal of the source 80, a variable tap 71 being connected to the first accelerating electrode 51. The curved deflecting member 70, as indicated above, is preferably at cathode potential. For simplicity in the drawing, in the guns shown in Fig. 1 the members 70 have been omitted. Heaters for the cathodes have not been shown but it is obvious that any suitable heater may be provided.

In the arrangement above described, the very low velocity guns G₃ and G₄ produce a large quantity of electrons which brings the mosaic 20 to a potential which is negative with respect to the collecting electrode 33 a very short time after a particular elemental area under consideration has been scanned. As the mosaic elements become gradually more negative with respect to final anodes 52 they approach the potential of the final anodes of the guns G₃ and G₄, and electrons from these guns no longer have energy enough to overcome the decelerating field between anodes 52 and the mosaic and can no longer reach the mosaic. The cathodes of guns G₁ and G₂, which are from 10 to 20 volts negative with respect to the anodes 52, are still negative with respect to the mosaic, and hence electrons from these guns continue to reach the mosaic, gradually lowering its potential.

By means of this invention, the iconoscope mosaic is made negative with respect to the collector electrode 33 during most of the cycle of operations as the mosaic is sprayed with a steady stream of electrons from the guns G₁, G₂, G₃ and G₄ or at least some of them, and by making use of several guns the whole target is sprayed uniformly, and moreover, in this arrangement the electrons from the auxiliary guns approach the target at an angle which is as near a right angle as it is possible to make it without cutting off light from the object.

As pointed out above, the beams at the surface of the target should overlap somewhat in order to improve the current density distribution over

the front face of the target. The current density distribution of the beam of one gun, as for example, gun G₁, along a line on the target in the plane of the drawing, may be represented by curve 1 in Figure 7 where this current intensity distribution of the beam in arbitrary units is plotted against the distance, also in arbitrary units, along the plane of the mosaic. A similar curve 2 for the beam of the gun G₂ is also shown in Fig. 7. The two curves 1 and 2 in Fig. 7 can be combined to give the resultant curve shown in Fig. 8. As indicated by the long flat-top portion of the curve of Fig. 8, by using the proper amount of overlap, the current intensity distribution of the electrons from the supplementary guns may be made substantially uniform over a relatively large portion of the mosaic surface. The degree of overlap necessary will depend, of course, on the particular gun structure and tube geometry. Overlapping beams from guns G₁ and G₂ have been indicated in Fig. 1 but the beams from the guns G₃ and G₄, which are also preferably made to overlap, have been omitted in this figure but merely for the purpose of simplifying the drawing.

In operation, the scanning current from the gun G should be adequate to restore each mosaic element to the equilibrium potential, slightly positive with respect to the collector, after scanning. The current produced by the electron spray from the auxiliary guns G₁, G₂, G₃ and G₄ is such that between scans an unilluminated portion of the mosaic reaches a potential which is negative with respect to the collecting electrode 33. An illuminated portion becomes less negative with respect to the collector because of the loss of photoelectrons between scans. Thus an unilluminated portion might become 8 volts negative just before scanning, while an illuminated portion becomes, for example, 6 volts negative.

When it is scanned by the beam from the gun G, an elemental portion of the mosaic surface 35 is raised to a potential substantially equal to the potential of the electrode 33 and the anode 52, and, immediately after scanning, such portion of the mosaic surface can be considered as being at the same potential as the anode 52. Under these conditions, electrons emanating from the cathodes 50 of the guns G₁ and G₂ will strike the mosaic with an energy corresponding to the potential V₁ supplied by that portion of the power supply consisting of batteries 23, 24 and 25. From the foregoing it can be seen that if the electrons leaving the cathode 50 are to lower the potential of the mosaic, as is desired, V₁ must be less than V₀, the voltage for unity secondary emission ratio. Thus an upper limit is placed on the allowable value of V₁.

As the electrons from the cathode 50 strike an elemental region of the mosaic, the potential of that region will be lowered gradually. It is obvious from the law of conservation of energy that the potential of the region cannot become lower than the potential of the cathode 50 which is at a potential V₁ with respect to the electrode 33. However, if the electrons are projected toward the mosaic at a considerable angle to normal (as in the Vance et al. arrangement), the lowest potential the mosaic can attain with respect to the member 33 is considerably less than V₁. Just how low a potential can be attained depends on the angle of projection and on the exact nature of the fields between the mosaic and the electrode 33. A simple case will be considered by way of example but the conclusions drawn will be very similar to those in many other cases.

The simple case considered will be that in which electrons are projected towards the mosaic at an angle θ with respect to the normal and in which the electrode structure is such that any electric field between the mosaic and the electrode 33 is substantially uniform and normal to the mosaic surface. Fig. 4 is a schematic diagram representing this condition showing the mosaic surface 35, the electrode 33, and various electron paths, ab , ac and ad from one of the auxiliary guns G_1 , G_2 , G_3 and G_4 to the surface 35, the path ab also representing the axis of the beam which is inclined at an angle θ with respect to a normal to the mosaic surface. As the electrons strike the mosaic 35, its potential is lowered with respect to the member 33 and there is set up, due to the change in potential, a force which acts on electrons approaching it, which force is toward electrode 33 and away from the mosaic 35. The uniform field assumed has no component parallel to the mosaic surface. When leaving the gun the electron travelling between the gun and the mosaic surface has a velocity component v_p , parallel to the mosaic surface and a component v_n , normal to the surface. These components are given by

$$v_p = \sqrt{2 \frac{e}{m} V_1 \sin \theta} \quad (1)$$

$$v_n = \sqrt{2 \frac{e}{m} V_1 \cos \theta} \quad (2)$$

where e is the charge of an electron and m is the mass of an electron.

Because there is no force parallel to the mosaic surface, v_p , the parallel component at the target is equal to v_{p0} , but v_n , the normal component at the target is less than v_{n0} . At the mosaic, by the law of conservation of energy, the following relation exists:

$$v_p^2 + v_n^2 = 2 \frac{e}{m} (V_1 - V) \quad (3)$$

where V is the potential of the mosaic with respect to the member 33. From Equation 3

$$\begin{aligned} v_n &= \sqrt{2 \frac{e}{m} (V_1 - V) - v_p^2} \\ &= \sqrt{2 \frac{e}{m} V_1 (1 - \sin^2 \theta) - V} \\ &= \sqrt{2 \frac{e}{m} (V_1 \cos^2 \theta - V)} \end{aligned} \quad (4)$$

It is seen that for values of V greater than $V_1 \cos^2 \theta$, v_n is imaginary, and thus it is clear that electrons cannot strike the mosaic 35 if it is at a lower potential with respect to 33 than $V_1 \cos^2 \theta$, where, as pointed out above, V_1 is the potential of the mosaic with respect to the cathode of the auxiliary gun and θ is the angle the electron trajectory makes with the normal to the mosaic surface. If the mosaic were at a potential lower than this, electron paths would take the parabolic form shown in the path ad , shown in Fig. 4. As the supply of electrons from the gun G to the mosaic 35 is the means depended on for lowering the mosaic potential, it is further obvious that the mosaic cannot attain a potential lower than $V_1 \cos^2 \theta$. It has already been explained that V_1 cannot be greater than V_0 , the voltage for unity secondary emission ratio. It thus follows that when low velocity electrons are used to lower the potential of the mosaic, the mosaic 35 cannot be

made negative with respect to 33 by a potential greater than V_x where

$$V_x = V_0 \cos^2 \theta \quad (5)$$

V_x can therefore be considered the maximum potential (negative with respect to the collecting electrode) that the mosaic surface can reach for a given set of conditions (shape and intensity of electrostatic fields, potential of cathode of auxiliary gun with respect to the mosaic, angle of electron approach to the target with respect to the normal, material of mosaic, etc.).

Now the operation of the present invention will be considered in the light of this fact.

In Fig. 5, the potential V with respect to the electrode 33 of an elemental region of the mosaic has been plotted with respect to time, the time between points 1 and 1' constituting a scanning interval. In Fig. 5a, the elemental area is assumed to receive little or no light from the object. Immediately after this element has been scanned (point 1 of Fig. 5a), V will be almost equal to zero—perhaps slightly positive because the energies of the secondary electrons caused by the high velocity scanning beam enable them to reach the electrode 33 under a slight retarding field. Electrons reaching the region from the low velocity gun cause the potential V to fall until the scanning beam again reaches the region, indicated by point 2, at which time the potential is V_a . Then the potential abruptly rises until at the end of scanning of this elemental region, indicated by point 1', it has the same value that it had at 1. Then low velocity electrons cause a fall of potential until the next scanning, at 2', etc.

Fig. 5b illustrates the conditions at a region illuminated by a strong light. In this case, many photoelectrons leave the mosaic during the arrival of slow electrons, and V falls less rapidly, reaching a value V_b (indicated by points 2 and 2'), V_b being less than V_a .

Now consider a case in which electrons from the low velocity gun are directed at the mosaic at a considerable angle θ to the normal, so that V_x is considerably smaller than V_0 . Let us consider the case of a low light intensity, as in the case represented in Fig. 5a. The result is illustrated in Fig. 5c. V starts to vary at about the same rate as in the case shown in Fig. 5a. However, V cannot reach the potential V_a which will give the correct signal, because V_x is smaller than V_a . Hence the response of the device is false for small light intensity.

It may be objected that this may be remedied by making the current from the low potential gun smaller, so that the potential does not fall so fast. Then for a weak light the potential would behave as shown in Fig. 5d, V falling to some value V'_a which is smaller than V_x . However, as shown in Fig. 5e, the device so modified will not respond to the strong light of Fig. 5b, for the potential cannot be lowered by the low velocity electrons since more photoelectrons are produced than there are low velocity electrons which arrive at the mosaic. Thus the modified device will give a false response to high light intensity.

Summing up, it can be said that to get a correct response to as wide a range of light intensities as possible, V_x must be as large as possible. V_x cannot be larger than V_0 , the potential for unity secondary emission ratio. V_x will be considerably smaller than V_0 if the low velocity electrons are projected at the screen at a large angle with respect to the normal. For example, in Fig. 2 of the Vance et al. United States Patent

2,147,760 for electrons striking the center of the mosaic from the low velocity gun 41, 43, 45, θ is shown in the patent to be approximately 52 degrees and $\cos^2 \theta$ is thus approximately .37, while for electrons striking the edge region of the mosaic remote from the auxiliary gun, θ is approximately 60 degrees and $\cos^2 \theta$ is approximately .23. Thus the device, and more particularly as regards the edge region of the mosaic, will be incapable of reproducing faithfully the wide range of light intensities that can be reproduced by means of the device of this invention.

In accordance with this invention, θ is made such a low angle with respect to the normal (by positioning the axis of the auxiliary gun or guns as near the normal to the mosaic as it is possible to do so (that V_x does not differ greatly from V_1 , or, that $\cos^2 \theta$ does not differ greatly from unity. For instance, for an angle with respect to the normal of $\theta=15$ degrees, $\cos^2 \theta=.93$, or V_x is only about 7 per cent lower than V_1 . This is to be compared with the arrangement shown in Fig. 2 of the Vance patent where it can be seen by measuring that the electrons strike the center of the mosaic at an angle of approximately 52 degrees, and thus $\cos^2 \theta=.37$, which makes V_x far less than the value obtained in accordance with this invention. In the arrangement according to the present invention, the angle between the electron path at the target and the normal to the target at that point is made so small that the cosine of that angle is not less than 0.9 (the angle being about 26 degrees or less).

There is a further point about angular incidence of electrons upon a target which is of importance. Work by various investigators has brought out that materials are better secondary emitters for glancingly incident electrons; in other words, V_0 will be smaller for electrons projected at a considerable angle to the normal, as proposed by Vance, than for electrons projected substantially normal, as in this invention. As it is desired to make V_x as large as possible, and V_x cannot be greater than $V_0 \cos^2 \theta$, this tends to further limit the range of light responsiveness and hence the usefulness of an arrangement utilizing electron incidence at a considerable angle to the normal.

The electron guns G_1 to G_4 , inclusive, each preferably emits a wedge-shaped beam, with rays somewhat like the partially opened leaves of a book. With this type of gun the electrons obviously reach various portions of the mosaic more nearly normal to the surface than would be the case with a gun giving a conical beam. Moreover, the problem of proper overlapping of beams, which is raised with the use of two or more guns, is satisfactorily solved. Conical overlapping beams give an area of overlap of uneven width while wedge-shaped beams give a constant width area of overlap. The proper amount of overlap depends on how rapidly the current density decreases near the edge of the beam and can best be defined as the amount of overlap which will make the current density on the mosaic most nearly constant.

It is obvious that more nearly normal incidence of a larger portion of the whole group of electrons emitted from the auxiliary source can be achieved by the use of two or more auxiliary guns than by the use of only one gun. However, if different parts of the mosaic are to be sprayed by different guns, and if the current density of the spray is to be kept substantially constant over the mosaic surface as is desirable for uniform operation of all portions of the mosaic, the

overlap of the beams must be carefully controlled. With conical beams it is obvious that the overlap will be variable in width and hence a uniform current density cannot be maintained. With guns such as those of the present invention the beam boundaries will be substantially linear, and with the proper amount of overlap the current density can be kept substantially constant over the whole mosaic.

As mentioned above, one type of operation proposed calls for the use of two kinds of slow electrons; an abundance of very slow speed electrons, say, 1 to 5 volt electrons, and a controlled current of faster slow electrons, say, 10 to 20 volt electrons. The reason for the 1 to 5 volt electrons will be apparent from Fig. 6, in which the potential of an elemental area or region of the mosaic is plotted versus time.

Fig. 6a is a digram of the operation with the "fast" low velocity electrons only spraying the screen. The response of the device depends on photoelectrons leaving the mosaic. Immediately after scanning an elemental area (see point 81 in the figure), photoelectrons cannot leave the region being discussed because it is positive with respect to the surroundings. Photoelectrons can leave the region only after the time (as shown at point 82) when this region becomes negative and the fields are favorable for the departure of photoelectrons. Thus the region is effective photoelectrically only for the period Δt_1 between points 82 and 83, and not for the whole period Δt between the time the scanning beam leaves the elemental area and the time it strikes that area again.

Fig. 6b is a diagram of the operation with an abundance of "slow" low velocity electrons as well as a controlled current of faster, but still relatively low, velocity electrons. In this case the "slow" low velocity electrons lower the potential of the region to a potential V_m (shown as points 84 and 84' and approximately the potential of the cathode of the "slow" low velocity electron guns with respect to the electrode 33) almost immediately after scanning. Thus the period of time Δt_1 when V is negative, is greater than when only "fast" low velocity slow electrons are used. When the mosaic potential reaches a potential which is approximately that of the cathode of the guns emitting the "slow" low velocity electrons, the electrons from those guns no longer strike the mosaic but return to the collecting electrode or other electrode elements at a more positive potential than the mosaic.

There is a further advantage in the use of nearly normal incidence. With slanting incidence as illustrated in Fig. 4 and in the Vance patent, electrons similarly directed strike various parts of the mosaic depending on the mosaic potential. For instance, ab represents a path for a small potential difference between the members 35 and 33, and ac represents a path for a larger potential difference between the members 35 and 33. This shifting of beam with potential makes it difficult to direct the beam properly at the mosaic, and might result in non-conformities of operation. It is obviated by the substantially normal incidence of the arrangement of the present invention.

It is possible to estimate the desired steady current supplied at the potential V_1 . Assume the time between scans is T and the capacitance between the face 35 and the back 30 of the mosaic

20 is C . Then to change all elements of the

mosaic by a potential αV_1 between scans requires a current

$$i_0 = \frac{\alpha V_1 C}{T} \quad (6)$$

Assume reasonable values in Equation 6, $C=12,000$ micro-microfarads, $V_1=15$ volts, $\alpha=\frac{2}{3}$, $T=\frac{1}{30}$ second, then $i_0=3.6$ microamperes. A slightly greater current will be necessary to compensate for secondary emission at less than unity ratio. V_1 is somewhat less than the voltage of impact at which the secondary emission ratio of the mosaic is unity. The factor α is always less than one. The larger α is the larger the light signal to which the device will produce a linear response, subject to the limitation, however, that if α approaches too closely to unity, the current from the low velocity guns to the mosaic will decrease toward the end of the period between scans because the mosaic will approach too closely the potential of the cathodes of these low velocity guns and some electrons will be turned back, leading to non-linearity of response. The larger the angle θ , the smaller α must be made (by adjusting the current flowing from the auxiliary guns) in order that no electrons from the relatively high speed low velocity guns shall be turned away from the mosaic. Not every electron approaching the mosaic from the auxiliary guns strikes it—or, at least, some electrons striking the mosaic cause other electrons to leave it. Thus, if for every electron reaching the mosaic from these guns, m electrons leave (where $m<1$), to cause a net current i_0 to flow to the mosaic, the auxiliary guns must supply a current of $i=i_0/(1-m)$.

With the arrangement described above, there is nothing gained by increasing the beam current beyond that necessary to restore each element to a uniform potential after scanning. If δ is the secondary emission ratio of the mosaic at the voltage of the scanning beam, the least beam current which can do this is that which can produce a net electron current equal to i_0 away from the mosaic. Thus the minimum scanning beam current would be

$$i_b = \frac{i_0}{(\delta-1)} \quad (7)$$

Assuming $\delta=5$ and the value of i_0 above computed, then $i_b=0.9$ microampere although it might be desirable to use a beam current somewhat larger than this.

While the use of two different types of supplementary or auxiliary guns is preferable in order to obtain the advantage stated above, it is of course obvious that all of them may be of one type, preferably of the type employing the higher velocity. This velocity is never high enough, however, to make their secondary emitting ratio greater than one.

Although the present invention has been described largely in terms of various illustrative embodiments, it will be apparent to those skilled in the art that the invention and its various features are susceptible of embodiment in a wide variety of forms within the spirit and scope of the appended claims.

What is claimed is:

1. The method of operating a cathode ray tube of the highly evacuated type having a mosaic of light-sensitive elements electrically insulated from each other and from a supporting structure and having a collecting electrode for electrons which is common to said elements, which method

comprises scanning said mosaic with a beam of high velocity electrons and spraying said mosaic with a stream of low velocity electrons, the axis of said stream being at an angle with respect to the normal to the mosaic surface which has a cosine falling within the range between 0.9 and 1.0

2. The method of operating a cathode ray tube of the highly evacuated type having a mosaic of light-sensitive elements electrically insulated from each other and from a supporting surface and having a collecting electrode which is common to said element, which method comprises scanning said mosaic with a beam of high velocity electrons, spraying said mosaic with an abundance of very low velocity electrons, and also spraying said mosaic with a smaller number of electrons having a speed which is low compared with the beam of high velocity electrons but which is higher than that of the very low velocity electrons.

3. In a cathode ray tube of the highly evacuated type having a mosaic of light-sensitive elements electrically insulated from each other and from a supporting surface and having a collecting electrode which is common to said elements, a plurality of electron guns so placed with respect to said mosaic that it is sprayed with low velocity electrons from said guns, which electrons approach said mosaic at an angle with respect to a normal to said mosaic at which the cosine thereof is at least 0.9.

4. In a cathode ray device, a mosaic of light-sensitive elements electrically insulated from each other and from a supporting surface, a collecting electrode common to said elements, a plurality of electron guns so placed with respect to said mosaic that it is sprayed with low velocity electrons which approach said mosaic at an angle of greater than about 64 degrees with respect thereto, the cathodes of the guns generating the low velocity electrons being out of sight of the mosaic so that material from the cathode cannot evaporate onto the mosaic.

5. The combination of elements as in claim 4 in which each of said electron guns comprises a deflecting electrode so that the electrons are emitted from each of said guns at an angle which is substantially at right angles with respect to the axis of the electrons emitted from the cathode of said gun.

6. In combination, an evacuated container having mounted therein a mosaic target of light-sensitive elements electrically insulated from each other and from a supporting electrode, means in said container for generating a beam of high velocity electrons and for causing said beam to scan every elemental area in turn of a field on said mosaic, means for applying radiations from an object or field of view to said target, means within said container for collecting secondary electrons emitted from said mosaic target when impacted by primary electrons from said beam, and a plurality of supplementary electron guns disposed around the normal to the center of the field on said target, said guns being so placed that streams of low velocity electrons emitted therefrom impinge upon said target at an angle of greater than about 64 degrees with respect thereto.

7. In combination, an evacuated container having mounted therein a mosaic target of light-sensitive elements electrically insulated from each other and from a supporting electrode, means in said container for generating a beam

of high velocity electrons and for causing said beam to scan every elemental area in turn of a field on said mosaic, means for applying radiations from an object or field of view to said target, means within said container for collecting secondary electrons emitted from said mosaic and target when impacted by primary electrons from said beam, and a plurality of supplementary electron guns disposed around a normal to the center of the field on said target, said guns each generating a beam of low velocity electrons which impinges upon said target and said supplementary guns comprising at least one gun from each of two types, one type comprising a gun which generates a beam of electrons of very low velocity, and the other type comprising a gun which generates a beam of a velocity which is low compared with the velocity of the beam of high velocity electrons but which is higher than that of the very low velocity electrons.

8. The combination of elements as in claim 7 in which the gun producing electrons of very low velocity emits more electrons than those of the second type.

9. The combination of elements as in claim 7 in which the supplementary guns comprise four guns which are so disposed around said normal that two guns of the first type are opposite each other and two guns of the second type are also opposite each other.

10. The combination of elements as in claim 7 in which each of said supplementary guns comprises a strip cathode, a first accelerating anode and a second accelerating anode.

11. The combination of elements as in claim 7 in which each of said auxiliary guns comprises a strip cathode, a first accelerating anode and a second accelerating anode, the potential of said second accelerating anode being at least substantially the same as that of the collecting electrode in said container, the cathodes of the guns of the first type being placed at a potential which is from 1 to 5 volts negative with respect to the potential of said collecting electrode and the cathodes of the guns of said second type being placed at a potential which is from 10 to 20 volts negative with respect to the potential of said collecting electrode.

12. In a cathode ray device, a screen or target, four electron guns, each of which generates a wedge-shaped beam, and means for directing the beams generated by said guns at said screen or target in such a way that the beams overlap at the target, the longitudinal axis of two of said beams each on opposite sides of said screen or target being generally parallel to one axis of said screen or target and the longitudinal axis of the other two of said beams, each on opposite sides of said screen or target, being generally parallel to the other axis of said screen or target.

13. Means for directing two beams of electrons toward a plane, said beams being of such shape and so directed that each of the regions of intersection of the beams with said plane is substantially rectangular and overlaps the other along one side thereof by the same amount throughout the overlap, the intensity of each beam at said plane being substantially constant throughout a considerable portion thereof adjacent said overlap portion and varying gradually from zero at

the side thereof bounding said overlap to substantially said constant value at the opposite side of said overlap portion, the gradients being the same for both beams and being such as to give substantially constant intensity throughout said overlap portion and said adjacent portions.

14. A target, means for directing two beams of electrons toward said target, said beams being of such shape and so directed that each of the regions of intersection of the beams with said target is substantially rectangular and overlaps the other along one side thereof by the same amount throughout the overlap, the intensity of each beam at said target being substantially constant throughout a considerable portion thereof adjacent said overlap portion and varying gradually from zero at the side thereof bounding said overlap to substantially said constant value at the opposite side of said overlap portion, the gradients being the same for both beams and being such as to give substantially constant intensity throughout said overlap portion and said adjacent portions, and means for generating a third beam of electrons and for causing it to scan said regions of intersection element by element.

15. In combination, an evacuated container having mounted therein a mosaic target of light sensitive elements electrically insulated from each other and from a supporting electrode, means in said container for generating a beam of high velocity primary electrons and for causing said beam to scan every elemental area in turn of a field on said mosaic, means for applying radiations from an object or field of view to said target, means within said container for collecting secondary electrons emitted from said mosaic target when impacted by primary electrons from said beam, said primary electrons having such velocity and number that said emission of secondary electrons leaves each element immediately after it has been scanned by said beam of primary electrons at an equilibrium potential which is positive with respect to the potential of said electron collecting member, and electron generating means for applying low velocity electrons to said mosaic in such quantity and at a velocity such that the potential of each of said elements is made negative with respect to that of the collecting electrode, said last-mentioned means being so placed with respect to the mosaic that the low velocity electrons approach said mosaic at an angle with respect to the normal thereto which has a cosine falling within the range between 0.9 and 1.0.

16. The combination of elements as in claim 15 in which said low velocity electrons are continuously sprayed over the entire field on said mosaic target.

17. The combination of elements as in claim 15 in which said low velocity electrons are applied to said target from a plurality of electron guns, the axes of which are symmetrically placed around the normal to the center of said field.

18. The combination of elements as in claim 15 in which said low velocity electrons are applied to said target from four electron guns, each generating a beam of substantially rectangular cross section at the plane of the mosaic target.

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