

April 10, 1945.

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2,373,396

ELECTRON DISCHARGE DEVICE

Original Filed May 1, 1941

2 Sheets-Sheet 1

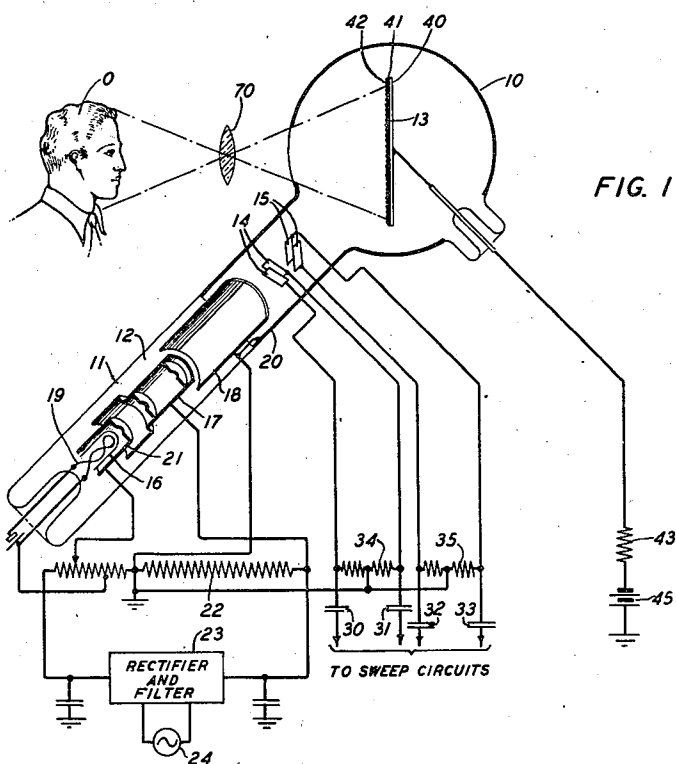


FIG. 1

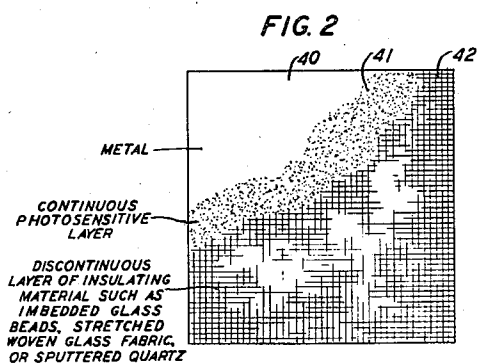


FIG. 2

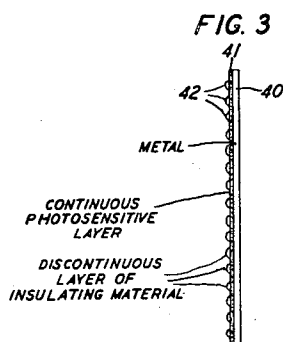


FIG. 3

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FIG. 5

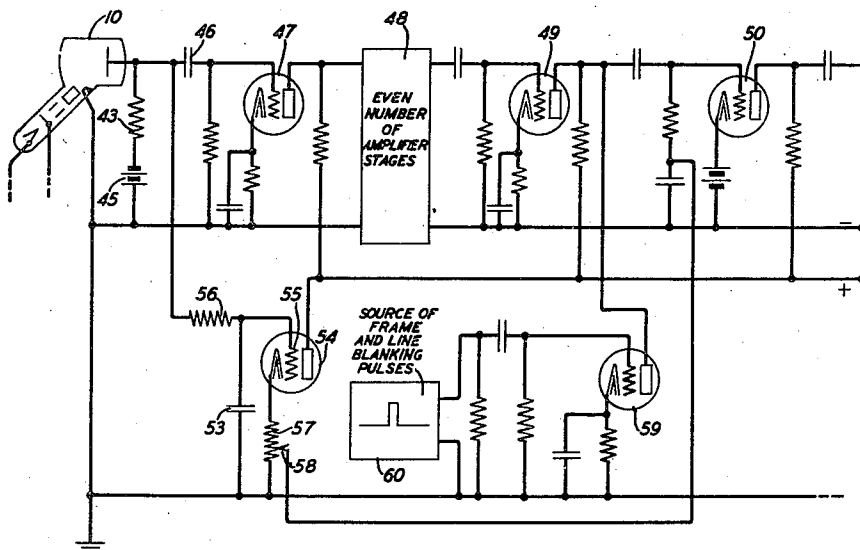
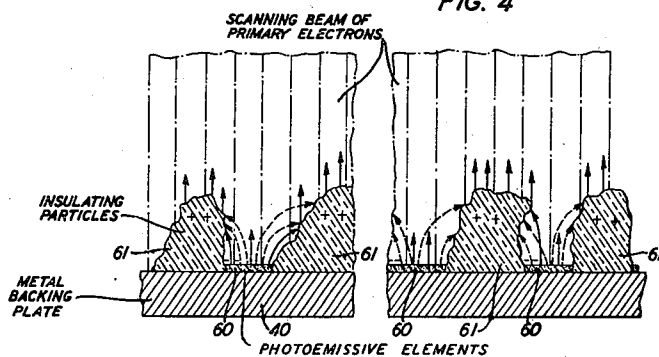


FIG. 4



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ELECTRON DISCHARGE DEVICE

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Original application May 1, 1941, Serial No. 391,306. Divided and this application April 4, 1942, Serial No. 437,715

2 Claims. (Cl. 315—12)

This application relates to electron discharge devices and more specifically to cathode ray tubes used as television transmitters.

One well-known cathode ray transmitter tube is known as the iconoscope. In one form of the iconoscope, the target comprises a metal backing plate, a sheet of mica or glass on the backing plate and a multiplicity of discrete globules of photosensitive material on the insulating material. Radiations from an object or field of view are applied to the photosensitive mosaic surface to cause the emission of photoelectrons, leaving the various elemental areas of the target charged to an amount depending on the light-tone values of the corresponding elemental areas of the object. A beam of electrons from a cathode ray gun so situated as to scan the globules of the target brings these charges to an equilibrium value and in so doing causes the formation of an image current through a resistance which is connected to the backing plate.

One of the disadvantages of the iconoscope above described is that photoelectrons and secondary electrons (caused by the primary beam striking the photosensitive surface of the target) are attracted towards more positively charged elemental areas of the mosaic instead of being directed to the collecting electrode as intended. This gives rise to spurious signals which detract from the appearance of the received image.

It is an object of this invention to provide a cathode ray tube suitable for television scanning in which this disadvantage is largely eliminated.

In a cathode ray television transmission tube according to this invention, potential differences between insulating portions of a target and a conducting signal plate or member, which potential differences are generated by secondary emission from the insulated portions of the target, are used to increase the photosensitivity and to decrease the spurious signals common in iconoscopes. In one embodiment of the invention, chosen by way of example to illustrate the principles of this invention, a tube is provided having a photoemissive layer or film (which may be continuous), this layer being coated on a conducting backing or signal plate which is preferably continuous. On the photosensitive surface, and in intimate contact with it, is placed a discontinuous layer of insulating material, for example, small glass beads slightly embedded in the photosensitive surface or stretched woven glass fabric formed upon it or quartz or other insulating particles sputtered or sprayed upon it, so that the continuous photosensitive surface is

partly exposed through openings between portions of the layer of insulating material. Preferably there are many insulating particles per picture elemental area (the size of the elemental area being determined by the size of the scanning spot). Each elemental area therefore comprises a number of insulating particles each closely adjacent a photoemissive surface. The insulating material and the beam strength are so chosen that the secondary emission ratio is greater than unity. If desired, metallic particles can be added to the insulating material to increase its secondary emission.

The theory of operation of this tube is as follows: A focussed electron beam scans the surface of the mosaic upon which an image of the object is also projected. When the beam in its passage over the target strikes the insulating portions of an elemental area of the mosaic target, an excess of secondary electrons over primary electrons is formed, which causes the potential of these insulating portions to reach a value which is positive with respect to the signal plate. The signal plate cannot appreciably change its potential since that is determined by its connection to ground or other reference point of fixed potential through a constant potential source, the negative pole of the source being connected to the signal plate. The field set up between the surfaces of the insulating portions of the target struck by the beam and the signal plate is such as to cause secondary electrons emitted from said insulating portions to leave the target substantially normal to its surface. These secondaries are collected by the collector electrode placed at a positive potential with respect to the potential of the signal plate. The beam of primary electrons also passes through the openings in the layer of insulating material and strikes the photoemissive surface of the signal plate, which also gives off secondary electrons. Due to their initial velocity and the accelerating field between the collector electrode and the signal plate most of these secondary electrons are drawn to the collector electrode, the potential of the insulating surfaces struck by the beam not being sufficient to more than deflect them. Some secondaries are attracted to the insulating surfaces struck by the beam but as the beam is still on these surfaces, these secondaries are either redirected to the collector electrode or take the place of other secondaries driven from these insulating surfaces by the beam. When the beam leaves any particular elemental area to travel over the remainder of the mosaic, the conditions which

exist at the elementary area are as follows: there are photoemissive portions of the elemental area which are closely adjacent corresponding elemental insulating surfaces which surfaces are charged to a positive potential with respect to that of the photosensitive plate. Radiations from the object or field of view, an image of which is formed on the target, cause photoelectrons to be emitted from the elemental photoemissive area in an amount which is a function of the light intensity falling on the area under consideration and these photoelectrons are accelerated toward and drawn to the nearest surface of positive potential which is the surface of the adjacent insulating particle. The photoelectrons, having only a relatively small initial velocity, are not directed towards the collector electrode although a small percentage of them may reach this electrode. Being situated very close to the area of emission, the field intensity due to the positive charges on the insulating surfaces struck by the beam is extremely high at the photoemissive surface; the photoelectric emission therefore occurs near voltage saturation conditions, that is, substantially all of the emitted photoelectrons are collected by the surfaces of the adjacent insulating portions struck by the beam. The insulating particles of brightly illuminated elemental areas attract more photoelectrons and therefore the potentials of their surfaces become more negative than those near less brightly illuminated elemental areas. When the beam again strikes this elemental area of the mosaic, secondary electrons are emitted from the element to such an extent that its insulating particles return to the equilibrium potential, which is positive with respect to the photoemissive surface. The impulse created by each elemental capacity (between the front surface of the insulating particles and the signal plate) returning to the equilibrium condition produces a current impulse in the signal resistor in the external circuit and a succession of these pulses produces the video current, which can be obtained by filtering the alternating component of the current through this resistor from the average emission current by a capacitative coupling. This average emission current is an indication of the average brightness of the scene focussed onto the plate and can therefore be used to determine or adjust the background control or height of the blanking impulse of the transmitted picture signals. Such an average current is not produced in the usual iconoscope as its formation is obviated due to the capacitative coupling between the backing plate and the photoemissive globules on the insulating surface. The element charging pulses may likewise be obtained by passing the secondary emission current reaching the collector electrode through a resistor to ground, the varying potential drop across which also constitutes a signal.

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 shows a cathode ray tube and its accompanying circuits and auxiliary apparatus to illustrate the use of a tube in accordance with this invention;

Fig. 2 is an enlarged front view, with portions broken away, of a target suitable for use in the tube shown in Fig. 1;

Fig. 3 is a side view of the target shown in

Fig. 2 except that the insulating mesh is replaced by discrete particles;

Fig. 4 is an enlarged elevation view of a target for a tube in accordance with the invention with arrows superimposed to aid in explaining the mode of operation of the invention; and

Fig. 5 shows an output circuit suitable for use with the tube of this invention.

Referring more specifically to the drawings, Fig. 1 shows, by way of example, a television transmitting arrangement including a tube of this invention. The tube 10 comprises an envelope 11 enclosing an electron gun 12 for generating, focussing and accelerating a beam of electrons towards a target 13 and two sets of deflecting plates 14, 16 and 15, 15 for causing the beam of electrons to scan every elemental area in turn of a field of view on the target 13. The electron gun arrangement 12 preferably comprises a cathode 16, a first anode 17 adjacent the cathode comprising a cylindrical portion having one or more metallic apertured diaphragms therein and a large cylindrical portion near the cathode, and a second anode 18 which is preferably a metallic cylinder of larger diameter than the smaller cylindrical portion of the first anode 17. A filament 19 is provided to heat the cathode 16. A conducting coating 20 on the inside walls of the tube between the portion of the tube adjacent the second anode 18 and the bulb portion thereof surrounding the target 13 is placed at the same potential as the second anode 18. The first anode 17 is placed at a relatively high potential with respect to that of the cathode 16, that is, of the order of 3000 volts, while the second anode 18 is placed at a potential which is positive with respect to that of the cathode but which is substantially negative with respect to the potential of the first anode, as for example from 300 to 900 volts with respect to the potential of the cathode. Due to the fact that the second anode 18 is at a negative potential with respect to that of the first anode 17, the secondary electrons emitted by the primary beam impinging upon one or the other of the diaphragms of the first anode are repelled by the second anode 18. Inasmuch as the electrons in the primary beam are of high velocity, the electrons thereof are decelerated by the second anode 18 but are not prevented thereby from reaching the screen or target. Between the first anode and the cathode is preferably arranged a control element 21 for varying the intensity of the primary electron beam, which element in the preferred embodiment constitutes a cylindrical member having a metal cap in which is located a circular aperture. This cylinder 21 is placed directly around the cathode 16. Suitable potentials for the various electrode elements are obtained from taps on a potentiometer resistance 22 which is connected across a rectifier or filter, represented in Fig. 1 by the block 23, which receives power from an alternating current oscillator 24. The electron gun briefly described above produces a beam at the target which is relatively free from secondary electrons and thus prevents distortion resulting from the imperfect focussing of these secondaries. For a more complete description of these distortions and of a gun of this type, reference may be made to Patent 2,217,168 issued October 8, 1940 to John R. Hefele and Gordon K. Teal. Any other suitable electron gun, however, may be used with the target for the tube of this invention as the present invention is not limited to any particular type of electron gun.

In order to cause the electron beam, generated by the electron gun apparatus described above, to scan every elemental area of the image or field of view on the screen or target 13, suitable deflecting means, such as, for example, the two pairs of electrostatic deflecting plates 14, 14 and 15, 15, the axes of which are located at right angles to each other, are provided. To the deflecting plates 15, 15 are applied deflecting voltages of frame 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 14, 14 to produce the horizontal deflection of the beam. Any suitable sweep circuit (not shown) may be used to generate these horizontal and vertical deflecting voltages. For example, reference may be made to Patent 2,178,464 issued October 31, 1939 to M. W. Baldwin, Jr. which discloses appropriate balanced sweep circuits for this purpose. Connections may be made from the balanced sweep circuits to the pairs of plates 14, 14 and 15, 15 by means of coupling condensers 30, 31 and 32, 33, respectively. High coupling resistors 34 and 35 are respectively connected across the pairs of plates 14, 14 and 15, 15. The mid-points of the resistors 34 and 35 are connected to the second anode 18 in order that the average potential of the deflecting plates is at all times substantially equal to the potential of the second anode 18. 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.

The screen or target 13 comprises (see as a first example Figs. 2 and 3) a metal backing member 40, which is preferably continuous and which will be designated the "signal plate," this term being considered broad enough to include a conducting mesh or a thin metal layer on a supporting member, a continuous photosensitive layer 41 of any suitable material sensitive to the radiations from the object or field of view to be electrically transmitted by the tube, such as, for example, caesium sensitized silver and a discontinuous layer 42 of insulating material, such as partially embedded glass beads (Fig. 3), stretched woven glass fabric (see Fig. 2) or sputtered quartz (Fig. 3). The discontinuous layer 42 of insulating material is preferably arranged in intimate contact with the photoemissive layer in such a way that the photosensitive surface is partly exposed through the interstices of the insulating material. An elemental area may comprise as many as a hundred or more elemental insulated particles. If desired, the photosensitive layer may be discontinuous, but each element of the surface must lay on and make contact with the signal plate. Fig. 4 is a greatly enlarged elevation view of another form of target wherein a discontinuous layer 60 of photosensitive particles is used, these particles being placed in the apertures of the insulating layer 61 consisting of a multiplicity of discrete insulating particles of quartz, aluminum oxide or other suitable material. The "hill-and-dale" nature of the target is shown in Fig. 4.

The targets (shown in Figs. 2, 3 and 4) may be made in various ways. In one form of target employing a discontinuous photosensitive layer, the backing plate comprises a sheet of silver upon which is sprayed aluminum oxide mixed with a suitable binder such as a thin solution of gum arabic. The binder is then burned off. The percentage of the target area covered by the alumi-

num oxide particles may be observed through a microscope. The target is then placed in the tube, the tube exhausted of air and gases, oxygen admitted and the silver oxidized by a glow discharge or by any other well-known means. Caesium is evaporated from a "pill" located in a side tube and the tube baked. Any other satisfactory technique for sensitizing mosaics may be used, if desired. In another form of target (see Fig. 4), quartz powder is mixed with a binder and sprayed on the silver sheet. The quartz particles 61 (beads) are not, strictly speaking, embedded in the silver—they are held against it by molecular attraction. The silver is then photosensitized to form a layer 60 by any suitable method. Fine particles of magnesium oxide or a lattice-work of insulating material may also be used as the insulating layer. The insulation layer is preferably only one particle thick, this being only a fraction of the diameter of the beam. The beam cross section covers a number of insulated particles. Treatment of the surface of the insulator in order to increase its secondary emission ratio, with, for example, finely divided oxidized metallic particles may be resorted to in order to increase the efficiency of operation.

Pulses are generally added to the video signal during the retrace period of the scanning cycle of the transmitter tube during which period no picture signals are generated. The amplitude of these pulses furnishes information to the receiving circuit as to the average illumination level of the scene which is being transmitted.

The picture signal which is obtained from the well-known iconoscope does not yield any information as to the average illumination of scenes which are focussed onto the mosaic to be transmitted. The signal pulses generated by a line of average gray on a black background will be identical with that of a white line on an average gray background. To supply this information of background level, the amplitude of these added pulses is manually controlled by a monitor operator or automatically by the photoelectric cell which can be so positioned near the iconoscope that it receives some light from the scene to be transmitted and so generates a current proportional to the average illumination of the image. This output of the phototube then controls the amplitude of the pulses which are inserted or added to the video signal during the blanking period.

In the arrangement according to this invention, a continuous current proportional to the picture illumination flows from the photocathode 41 or 60 to the insulated elements 42 or 61 of the mosaic during the entire frame time during which it is exposed to radiations from the object O. This current flows through the output resistor 43 which is connected between the signal plate 40 through the source of potential 45 to ground potential which in the arrangement shown is also the potential of the final anode 20 in the tube 10.

Secondary electron emission from the photocathode 41 due to the bombardment of its surface by the electron beam also flows through the resistor 43, but since the secondary emission of such a cathode is virtually independent of its illumination, this current should remain substantially constant during the whole scanning period.

The pulses produced by the discharge of the elemental capacitors of the mosaic when the beam scans the surface of the mosaic constitutes a signal current which likewise flows through this output resistor. These pulses are produced as follows (referring by way of example to Fig.

4): When the beam strikes the insulated portions 61 of an elemental area of the mosaic, the secondary electrons which are emitted from those portions cause them to become charged to a positive potential with respect to their surroundings as indicated in Fig. 4. When the beam strikes the photosensitive portions 60 of the elemental areas of the mosaic through the interstices of the insulating material, the photosensitive layer 60 cannot change its potential as it is coated on and therefore electrically connected to the signal plate 40. As more secondary electrons are emitted from the insulating portions 61 of the mosaic target 13 than there are primary electrons in the scanning electron beams, the insulating portions 61 are brought to a positive equilibrium potential with respect to the signal plate and the photoemissive coatings 60 thereon. Minus signs have been affixed to the elements 60 in the drawing as the potential of these elements is negative with respect to the potential of the elements 61. The field between the insulating portions 61 of the target and the photoemissive portions 60 thereof is such as to cause the secondary electrons to leave the target substantially normal to its surface and to be collected by the collector electrode 20 which is placed at a positive potential with respect to the potential of the signal plate 40 by the source of potential 45. The potential of the source 45 varies from a value near zero to about 100 volts depending on the surface used, the geometry of the tube, etc. At the higher voltages, however, the focus of the scanning beam becomes slightly impaired. Tubes have worked satisfactorily with this potential difference less than 20 volts. When the beam leaves this particular element to travel over the remainder of the mosaic, the conditions which exist at the elemental area are believed to be as follows: There are photoemissive portions 60 in each elemental area which are closely adjacent corresponding elemental insulating surfaces 61 which surfaces are charged to a positive potential with respect to that of the photosensitive elements 60. Radiations from the object or field of view O cause photoelectrons to be emitted from the elemental photoemissive surfaces in an amount which is a function of the light intensity falling on the elemental area and these photoelectrons (as pointed out above) are accelerated towards and drawn to the nearest surface of positive potential which is the surface of the adjacent insulating particles 61. Being situated very close to the area of emission, the field intensity due to the positive charge is extremely high at the emissive surface; the photoelectric emission therefore occurs near voltage saturation conditions. The insulating particles 61 of brightly illuminated elemental areas collect more photoelectrons and are thus negative in potential with respect to those near less brightly illuminated elemental areas. The paths of the photoelectrons are represented by dotted line arrows in Fig. 4. When the beam again strikes this elemental area of the mosaic, secondary electrons are emitted from the insulated elements to such an extent that the insulating particles of the elemental area return to the equilibrium potential. As pointed out above, the electric field of the photosensitive surface which is comparatively very negative, extending through the interstices of the insulating material, aids in focussing and accelerating the secondary electrons from the insulating portions in a direction normal to the target surface as shown by the full line arrows in Fig. 4. They therefore

travel directly away from the target surface since the charge on neighboring elemental areas tends to become nullified by this negative field. Preferably the insulating particles or elements 61 have portions which have a higher elevation from the surface of the backing plate 40 than do the photosensitive particles 60 to insure maximum directive fields. The impulse created by each elemental capacity (between the front surface of the insulating particles and the signal plate) returning to the equilibrium value produces a current impulse in the signal resistor 43 in the external circuit and a succession of these pulses produces the video current. The above is believed to be the correct theory of operation as tubes constructed in accordance with this invention have operated satisfactorily in a manner to indicate this.

There are obtained across the resistor 43 pulses of potential due to the successive discharge of the individual elements, as well as a potential proportional to the average illumination which varies as the average scene illumination varies superimposed upon an unvarying potential which is due to the emission of secondary electrons from the photosensitive plate. This constant potential is quite useless in the operation of the device as a camera tube and can be balanced out before transmission.

Reference will now be made to Fig. 5 which indicates schematically a circuit for utilizing the output current of the camera tube shown in Fig. 1. The current flowing through the resistor 43 is impressed through a coupling condenser 46 to the tube 47 the output circuit of which may be connected through an even number of amplifier stages represented by the box 48 to a tube 49, the output circuit of which is connected in parallel with the output circuit of tube 59, to the input circuit of tube 50. The input circuit of the tube 59 is connected to a source 70 of rectangular pulses. These pulses are of line and frame repetition frequency and of such a width as to blank out all of the video signals generated during the return time of the scanning cycle of the beam in the transmitter tube. The amplifiers 47, 48 and 49 transmit only the alternating current components of the signal produced by the tube 10 since all of the direct and slowly varying components are removed by the coupling condenser 46. The potentials generated by the tube 10 are also transmitted to the grid 55 of a high vacuum tube 54 through the resistance-capacity filter comprising resistance 56 and capacity 53. This resistance-capacity arrangement filters out all but the slowly varying and constant potential. Connected in the cathode-anode circuit and also in the cathode-grid circuit of the tube 54 is resistor 57 having a variable tap 58 thereon which is connected to the input circuit of the tube 50. The bias of the tube 50 is, therefore, dependent on the intensity of the continuous and low frequency components of the current flowing through the resistor 43. The amplitude of the blanking pulses is controlled by adjusting the grid potential of the tube 50 which adjustment is performed automatically by the directly coupled amplifier tube 54, the output voltage of which controls the grid bias of the tube 50. There is then obtained in the output of the tube 50 picture signal pulses due to the scanning of the mosaic by the electron beam and pulses at the end of each line and frame which are indicative of the average illumination of the mosaic. At the receiver, the amplitude of these blanking pulses is utilized,

by well-known methods, to set the grid bias of the receiving cathode ray tube which adjusts the background level of the illumination of the receiver tube screen, upon which grid the video signal is superimposed. While a specific circuit arrangement has been described, it is obvious that other circuit arrangements may be used with the tube above described.

The element charging pulses may likewise be obtained by passing the secondary emission current reaching the collector electrode 20 through a resistor to ground, the varying drop across which also constitutes the signal which may be used in connection with a circuit of the type shown in Fig. 5.

The advantages of the arrangement shown in Fig. 1 may be summed up as follows: (1) Photoemission occurs under saturated voltage conditions from a continuous surface. (2) Secondary electrons have a field which directs them normal to the surface and away from neighboring elements. This effect would eliminate the "shadows" and loss of contrast experienced with tubes of the usual iconoscope type. (3) The continuous photoelectric surface presents no difficulty in manufacture. In making photosensitive mosaics for iconoscopes there is great difficulty in keeping the elements discrete, as well as inability to measure the true sensitivity of the surface. (4) A continuous current indicative of the average illumination of the beam focussed on the target of the pick-up tube flows from the sensitive surface thereof which current can be used to determine the background level of the transmitted picture. (5) The tube of this invention employing a caesium-oxygen-silver surface has a much stronger response in the red and related portions of the spectrum than has the ordinary iconoscope. This is believed due to the increased field acting on the photoemission bringing the sensitivity more nearly in line with that of the caesium-oxygen-silver photocell than is that of the ordinary iconoscope.

Various modifications may be made in the embodiments described above without departing from the spirit of the invention the scope of which is indicated by the appended claims.

This application is a division of application Serial No. 391,306 filed May 1, 1941.

What is claimed is:

1. A cathode ray device comprising means for generating a beam of electrons, a target structure

for said beam comprising a base member consisting of a plate-like backing element of material having high electrical conductivity and photoemissive material on the side of said element facing the beam and adherent to said element, and a layer of insulating material adherent to the side of said base member facing the beam, said layer of insulating material having a multiplicity of minute discrete openings each extending through said layer in a direction generally perpendicular to said base member to photoemissive material on said backing element whereby the photoemissive material at the bottoms of said openings is directly exposed to the beam and to image-bearing radiations when the latter are applied to the side of the target facing the beam, means for causing said beam to scan said target element by element, and means cooperating with said above-mentioned means and said target to set up voltage variations corresponding respectively to the intensities of radiations incident upon the different ones of said scanned elements when irradiated, said last-mentioned means comprising a collecting electrode element for receiving secondary electrons emitted from said target when said beam strikes it.

2. A cathode ray device comprising means for generating a beam of electrons, a target structure for said beam comprising a single layer of particles of insulating material each particle adherent to a base member consisting of a thin, plate-like element of material of high electric conductivity having photo-emissive material adherent to the surface thereof facing said beam, said particles being on the side of said base member facing said beam, being closely spaced and forming valleys therebetween with photoemissive material at the bottom of the valleys whereby it is directly exposed to the electron beam and to image-bearing radiations when the latter are applied to the side of the target facing the beam, means for causing said beam to scan said target element by element, and means cooperating with said above-mentioned means and said target to set up voltage variations corresponding respectively to the intensities of radiations incident upon the different ones of said scanned elements when irradiated, said last-mentioned means comprising a collecting electrode element for receiving secondary electrons emitted from said target when said beam strikes it.

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