May 2, 1939. V. K. ZWORYKIN 2,157,048

TELEVISION SYSTEM

Original Filed July 17, 1930 2 Sheets-Sheet 1

Fig. 1.

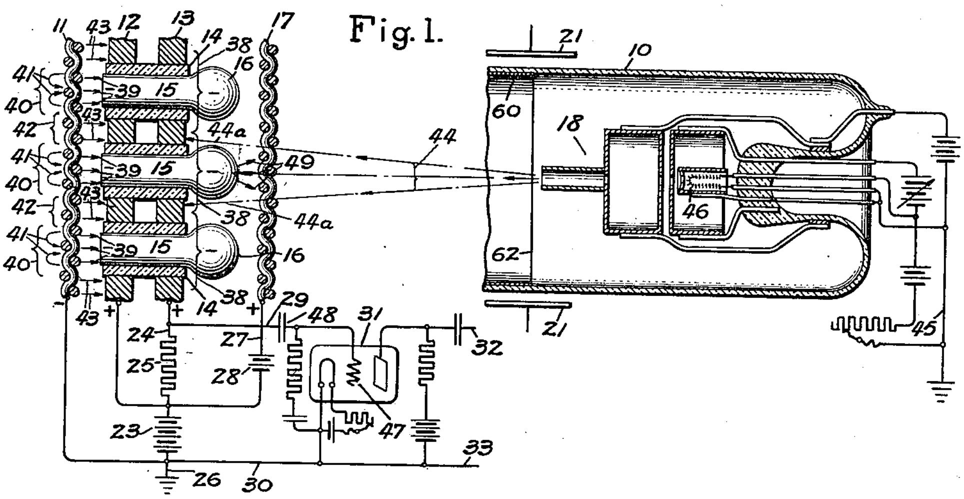


Fig. 2.

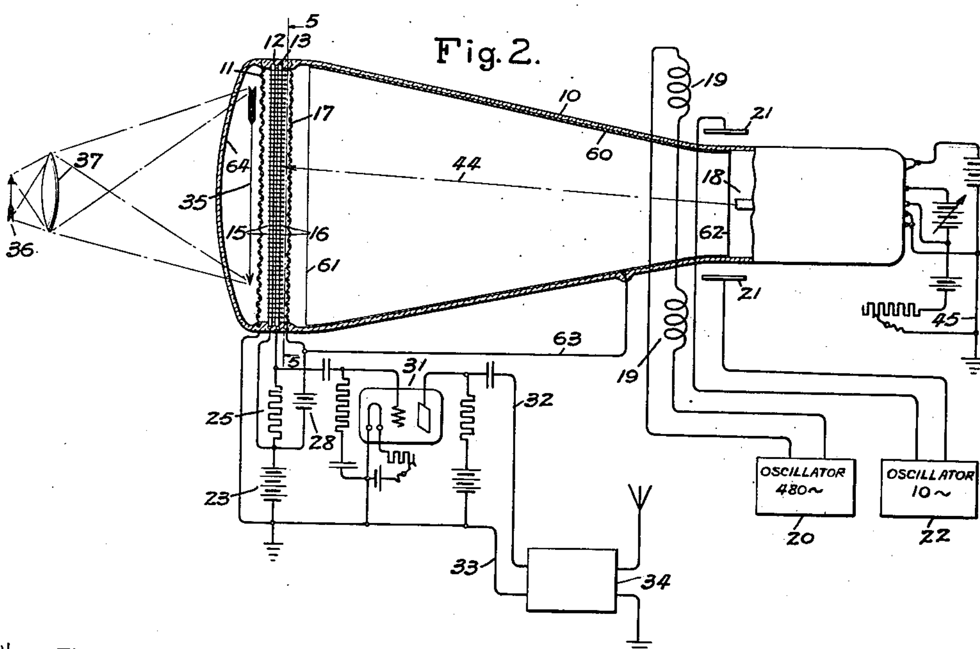


Fig. 3.

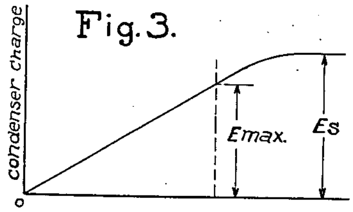
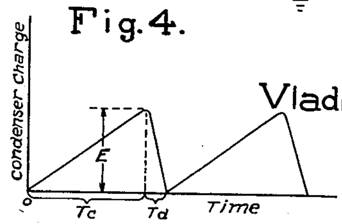


Fig. 4.



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Original Filed July 17, 1930 2 Sheets-Sheet 2

Fig.5.

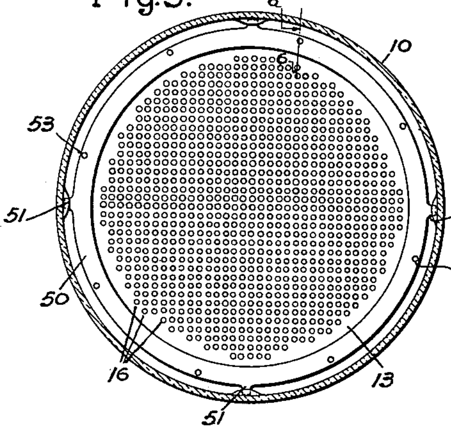


Fig.6.

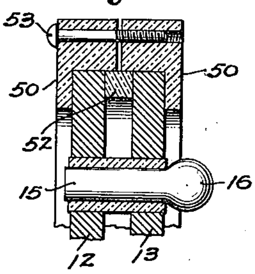


Fig.7.

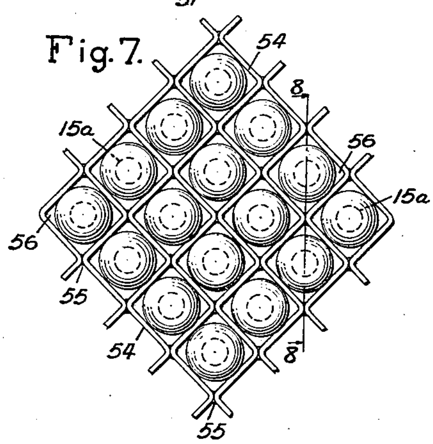


Fig.8.

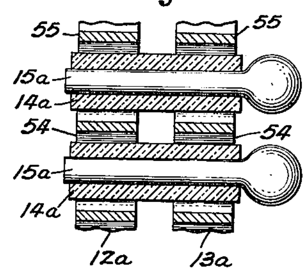
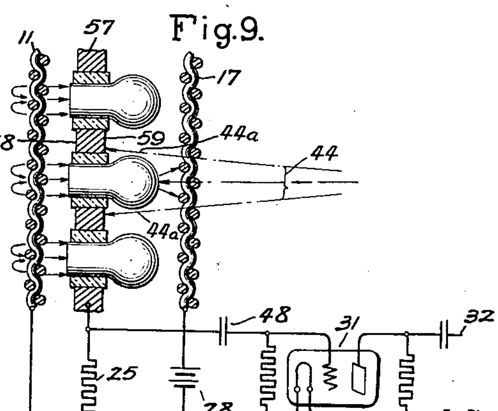


Fig.9.



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Patented May 2, 1939 2,157,048

UNITED STATES PATENT OFFICE

2,157,048

TELEVISION SYSTEM

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Application July 17, 1930, Serial No. 468,610
Renewed January 30, 1937

13 Claims. (Cl. 178—7.2)

My invention relates to improvements in television systems, and it has particular relation to systems of the type wherein the scanning devices, at both the transmitter and receiver, are devoid of moving mechanical elements.

It has been proposed, heretofore, to employ for television transmission a cathode ray tube wherein the cathode comprises or is made up of a large number of relatively small photoelectric cells exposed to the cathode ray for scanning thereby. This construction, while providing for satisfactory results, has been found to introduce difficulties as regards practical construction of the cathode unit. Prior art construction of the general type referred to is disclosed by my copending application Serial No. 448,834, filed May 1, 1930, assigned to the Westinghouse Electric and Manufacturing Company.

One of the objects of the present invention, therefore, is to provide an improved method for television transmission and apparatus therefor which will not only avoid the difficulties referred to in the construction proposed heretofore, but will be more satisfactory and produce better results in the way of possibilities for sharper and, generally, better reception at the receiver.

In accordance with my invention, an image of the object at the transmitting end is projected onto a single photoelectric or light-sensitive cathode, the occurring electron emission from the latter is accumulated on an anode in the form of a relatively large number of small electrostatic charges spaced uniformly over the area of the anode and at relatively small distances apart, a cathode ray is developed and is caused to scan the anode and effect successive neutralization of these electrostatic charges during each scanning cycle, and the charges are utilized to control the influence of the scanning ray with respect to a circuit in a suitable radio or other transmission system.

Further, in accordance with my invention, television transmission is effected, in part, by accumulating electrostatic charges at spaced regions or spots over an area commensurate with the area of the image to be transmitted, the magnitude of the charge at any region or spot, at any instant, corresponding to the degree of light-intensity at that instant on a corresponding region or spot of the image.

Still further in accordance with my invention, improved television transmission is provided for by projecting a light image of the object onto a single unitary light-sensitive cathode, developing an undistorted electrical image from the occurring electronic emission from the cathode, and scanning the electrical image by a cathode ray or beam to influence a circuit in a suitable radio or other transmission system.

My invention resides in an improved method and apparatus of the character hereinafter described and claimed.

For the purpose of illustrating my invention, an embodiment thereof is shown in the drawings, in which

Fig. 1 is an enlarged fragmentary diagrammatic view of a television transmission system embodying the present improvements;

Fig. 2 is a diagrammatic view of a television transmission system embodying the present improvements;

Figs. 3 and 4 are graphical illustrations;

Fig. 5 is a sectional view, the section being taken on the line 5—5 in Fig. 2;

Fig. 6 is an enlarged sectional view, the section being taken on the line 6—6 in Fig. 5;

Fig. 7 is an enlarged fragmentary view, showing a modification;

Fig. 8 is a section taken on line 8—8 in Fig. 7; and

Fig. 9 is a view similar to Fig. 1, showing a modification.

The cathode ray tube 10 is provided with a single unitary photoelectric cathode 11 in the form of a fine mesh screen of suitable light-sensitive material characterized by the fact that electron emission occurs from a surface of the material when the same is exposed to light and at a rate which corresponds to and increases with increase in light-intensity.

A pair of relatively thin plate electrodes 12 and 13 are supported as shown in spaced relation to each other and in planes parallel to the plane of the cathode 11. These electrodes are provided with apertures through which tubular insulating members 14 extend, as more clearly shown in Fig. 1. A plurality of metallic elements 15, having head portions 16 at one end thereof, extend through the members 14.

An electrode 17, in the form of a fine mesh screen, is supported in the tube 10 in close proximity to the head portions 16.

The number and arrangement of the elements 15 are chosen to suit particular conditions. For the purpose of transmitting an image or picture framed in a five inch square, it is contemplated to employ sixty-four hundred of the elements 15 and arrange the same uniformly over the area in eighty evenly spaced parallel rows, each row containing eighty evenly spaced elements.

The tube 10 is provided with an electron gun 18 of any suitable construction operable to develop a cathode ray or a beam of such rays and to project the same onto the elements 15. An example of the construction contemplated for the electron gun is disclosed in my co-pending application Serial No. 407,652, filed November 16, 1929, and assigned to the Westinghouse Electric and Manufacturing Company.

The cathode ray or beam is caused to scan the area within the image or picture frame, there being, for example, twelve to twenty scannings of such area each second, the manner of scanning being such that the ray or beam strikes each region of such area at and immediately about each of the head portions 16 during each scanning cycle. In the present embodiment of my invention, the means or apparatus for such purpose is indicated as being of the well known type comprising, for example, coils 19 supplied by a 480 cycle oscillator 20 and plates 21 supplied by a 10 cycle oscillator 22, the coils 19 providing for horizontal deflection of the ray or beam of rays and the plates 21 providing for vertical deflection. This type of apparatus and the associated parts and connections therefor are disclosed in more detail in my Letters Patent No. 1,691,324 of Nov. 13, 1928.

The electrode 12 is connected to the positive side of a battery 23, while the cathode 11 is connected to the negative side of this battery. An electrostatic field is thus developed and maintained between the cathode 11 and the adjacent face of the electrode 12. The distance between adjacent faces of the cathode 11 and the electrode 12 is relatively small, that is, of the order of one eighth of an inch. The electrostatic lines of force are therefore parallel to each other and perpendicular to the adjacent parallel faces of cathode 11 and the positive electrode or anode 12.

The electrode 13 is connected as shown to the end 24 of a resistance 25, the other end of this resistance being connected to the positive side of the battery 23.

The negative side of the battery 23 is grounded through connection 26.

The electrode 17 is maintained at a fixed positive potential by connecting the same to the positive side of the battery 23 through a connection 27. A battery 28 may be included in the connection 27 to increase this potential if desired.

The input leads 29 and 30 of a suitable amplifier 31 are connected across the series-connected resistance and battery 23. The output leads 32 and 33 of this amplifier are connected in the usual manner to the well known associated apparatus and parts, all indicated by reference numeral 34, of a suitable radio or other transmission system.

The image 35 of an object, indicated by the arrow 36, is projected through a suitable lens or lens system 37 onto the light-sensitive surface of cathode 11.

The manner or principle of operation of the present transmitting system is believed to be as follows:

Each of the elements 15 and the respective regions of electrodes 12 and 13 immediately about the same constitute a condenser which is continuously charged by the electron emission from cathode 11, indicated by the arrows 39. This electron emission develops at the light-sensitive surface of cathode 11 upon which the light image is projected, the degree or rate of such emission from any particular spot or point corresponding to and increasing with the light intensity thereon. The entire number of electrons emitted from the light-sensitive surface of cathode 11 reach the adjacent face of the composite anode. The electrons emitted from the regions or spots 42 of the light-sensitive surface reverse their direction of travel upon leaving this surface, under the influence of the electrostatic field, pass through the openings in the cathode 11 and move toward the anode along the parallel electrostatic lines of force between the adjacent faces of the cathode 11 and the electrode 12, as indicated by the arrows 43. These electrons then leak to ground by way of the battery 23 and the connection 26. Electrons emitted from the regions or spots 40 between those designated by reference numeral 42 also reverse their direction of travel in like manner upon leaving the light-sensitive surface, as indicated by the arrows 41, under the influence of the electrostatic field, move toward the anode along the parallel electrostatic lines of force between the adjacent faces of the cathode 11 and the electrode 12, as indicated by the arrows 39, and contact with the elements 15, charging the same respectively to certain values as determined by the illumination of corresponding regions or spots 40 on the cathode 11.

The charge curve of each condenser is shown in Fig. 3, wherein E_s is the charge for saturation and E_{max} the maximum charge which any condenser can receive under any conditions of illumination of the object. That is, where a particular region or spot 40 on the light sensitive surface of cathode 11 is one of the brightest spots of the image, the particular condenser of which the adjacent element 15 is a part will receive the maximum charge, E_{max}. No condenser is, therefore, ever charged to saturation, the charging action always being confined to the straight-line portion of the charge graph, and between the limits zero and E_{max}. The manner in which this action is obtained will hereinafter more fully appear.

For the purpose of simplification, the influence or effect of the ray 44 of electrons from the source or gun 18 will be considered in a given instance, as the same strikes one of the regions or spots 38 of the composite anode 13—15 during the scanning action or cycle of the beam of electron rays focused on and directed to this region or spot at the instant.

The electrons of the ray 44 reach the screen or positive electrode 17 at a velocity corresponding to the potential difference between this electrode and the cathode 46. Part of these electrons strike the wire of screen 17 and are absorbed thereby and pass or leak to ground by way of the batteries 28 and 23 and the connection 26. The electrons which pass through the openings of the screen 17 strike directly the region or spot 38 on the exposed face of the composite anode, part of these electrons striking the head portion 16 of element 15, the remainder striking the surface portion of the electrode 13 immediately adjacent or about the element 15, as indicated by the arrows 44a.

When all the elements 15 are uncharged, or charged to the same potential, the same number of electrons strike each of these surface portions of the electrode 13 for all positions of the ray 44 with respect to the composite anode. Therefore, when there is no image on the light-sensitive surface of the cathode 11, or in other words, when the illumination is uniform over such surface, the electrons of the ray 44 contacting with the exposed surface of the electrode 13, as indicated by the arrows 44a, cause a direct current at constant voltage to flow through the resistance 25, and thence by way of the battery 23 and ground to the cathode 46, the magnitude of the direct current being determined by the constant number of electrons striking the electrode 13 each instant of the scanning period.

When, however, any of the elements 15 are charged, or the charge thereof varies from an initial value, due to projection of an image upon the cathode 11 and resulting variation in light intensity on the different regions or spots 40, the number of electrons which reach any particular region of the electrode 13, as indicated by the arrows 44*a*, will vary under control of the charge E on the associated element 15. This variation in the number of electrons which reach any particular region of the electrode 13 will be inversely proportional to the value of charge E on the associated element 15 to which the ray 44 is directed at the instant, and, it follows, will be also inversely proportional to the magnitude of light intensity on the adjacent and corresponding region or spot 40 of the image 35. Variation in the number of electrons reaching any scanned region of the electrode 13 at any instant of the scanning period effects variation in or modulation of the initial direct current voltage across the resistance 25. The potential on the grid 47 of the amplifier 31 varies in accordance with such variation in voltage drop across the resistance.

The action just described is attributed to a negative field developed at the head portion 16 of each element 15, the field strength being determined by and varying with the charge E. This field has a retarding or opposing effect with respect to the entire number of electrons which pass through the screen 17. If the charge E is relatively small, this retarding effect or influence will also be small, and the number of electrons striking the electrode 13 will be correspondingly great. Conversely, if the charge E is relatively great, this retarding effect or influence will also be great, and the number of electrons striking the electrode 13 will be correspondingly small.

The full significance and advantage of the conditions in my present improved apparatus which allow or provide for storage or accumulation of the electrostatic charges E during a relatively large period of time, that is, during the entire period of the picture or scanning cycle of the ray 44, will be better appreciated upon comparison with conditions in television systems proposed heretofore. In these systems, the period of time during which the photocell or photocells of the transmitting apparatus are exposed to the influence of the light from each spot or region of the image is very short. For example, in such apparatus for transmitting a picture of one hundred lines with one hundred picture elements to each line, this period of time would be only 10^{-4} times the picture or scanning period. If the scanning rate is twelve pictures per second, for example, the number of electrons released by the photocell at any instant is measured by the photrons of light emitted in

$$\frac{1}{12}\times10^{-4}$$

seconds from the particular spot of the object being scanned at this instant. It will therefore be appreciated that even for the brightest spot of the object, the number of light photrons available or effective to influence the photocell during each scanning period is extremely small.

In my present improved apparatus, on the contrary, the light photrons emitted from each spot of the image are all effective with respect to the light-sensitive part of my apparatus during the entire picture or scanning period, or in other words, for a period 10,000 times longer than has been the case in apparatus proposed heretofore. For similar conditions, therefore, the available or effective photoelectric current provided by the present improved transmitter is ten thousand times stronger than that in the prior construction referred to.

Those electrons of the ray 44 which strike the head portion 16 of the element 15 induce or cause emission of electrons from this element to the screen 17, as indicated by the arrows 49, to effect discharge of the charge E within the time T*d*. This electron emission is secondary with respect to that indicated by the arrows 39, 41 and 43. The electrons of the secondary emission thus drawn to or absorbed by the screen 17 pass to ground by way of the batteries 28 and 23.

The condenser charge E, by the action explained above, controls the extent or degree of influence of the ray 44 with respect to the electrode 13 in effecting variation in or modulation of the potential on the grid 47 of the amplifier, the amount of such variation being inversely proportional to the amount or magniture E of the charge.

It will be understood that each of the condensers, of which the elements 15 are parts, are in effect, being continuously charged due to the continual electron emission from the light-sensitive surface of the cathode 11, collection of the charge taking place during the full period of the picture being transmitted, or in other words, during the full period of the scanning cycle of the ray 44. This period will be, for example, of the order of one twelfth to one twentieth of a second.

The time allowed for each element 15 to accumulate its respective charge E is that elapsing between the times of succeeding contacts or impacts of the ray 44 on the particular region or spot 38 of the composite anode with which the element is associated. The scanning rate of the ray 44 is made so great that, although each element 15 is being continuously charged in the manner explained, the charging time Tc is never great enough to permit accumulation of a charge greater than E*max* for the brightest spot or region of the light image. The graph of Fig. 4 is intended to represent a condition wherein T*d* is approximately one-twelfth of Tc.

From the foregoing, it will be seen that an electrical image, in the form of a large number of electrostatic charges, is developed on the anode structure 13—15, this image in effect being projected without distortion from the light-sensitive cathode 11 upon which the light image 35 is projected, the amount or degree of electrostatic charge E at any spot or region on the electrical image corresponding to and varying with the degree of light intensity on the respective adjacent spot or region of the light image. By scanning the electrical image with the cathode ray or rays 44, the potential on the grid 47 of the amplifier is varied or modulated in exact accordance with the different degrees of light intensity on the various spots or regions of the light image, the number of scannings each second being adequate to provide for satisfactory reception of a moving image at the receiver.

As shown in Figs. 5 and 6, the electrode plates 12 and 13 may be clamped at their edges between complementary supporting rings 50 of suitable insulating material and provided with lugs 51 embedded in the wall of the tube 10. A spacing ring 52 of insulating material is interposed between the plates 12 and 13, as shown. Screws or other suitable means 53 may be employed to clamp the rings 50 together.

As a modification, it is contemplated to substitute for the mesh cathode 11 a photo-sensitive semi-transparent film deposited on the inside face 64 of the tube 10 at the large end thereof. In such case, the image 35 would be projected upon the film to develop an electron emission corresponding to and effective for the same purpose as that in Fig. 1, as represented by the arrows 39, 41 and 43.

The anode 13—15 may be constructed in different ways to suit different requirements, each construction, however, being characterized by the fact that it will receive the electrical image developed at cathode 11 and projected therefrom as indicated by the arrows 41 and 39. For example, in the construction shown in Figs. 7 and 8, the anode comprises two electrode sections or units 12*a* and 13*a* corresponding, respectively to the plates or electrodes 12 and 13 in Fig. 1. Each of the electrodes 12*a* and 13*a* is made up of a plurality of strips 54 of nickel or other suitable material. These strips are corrugated and arranged as shown, the engaging edges being secured together in any suitable manner such as by spot welding, as indicated by reference numeral 55. Tubular insulators 14*a* carrying the metallic inserts 15*a* extend through the openings 56 between adjacent strips 54, and have a close fit with respect to the latter.

The electrodes 12 and 13 in Fig. 1 may be combined into a single electrode 57, as shown in Fig. 9. In this case, the action or principle of operation is the same as that in the arrangement or system of Fig. 1, the lefthand surface portion 58 of the electrode 57 corresponding to and functioning in the same manner and for the same purpose as the electrode 12 in Fig. 1, the righthand surface portion 59 corresponding to and functioning in the same manner and for the same purpose as the electrode 13 in Fig. 1. The single electrode 57 may be fabricated or built up in accordance with the modified construction in Figs. 7 and 8, in which case one of the sections 12*a* and 13*a* would be omitted.

It is contemplated to provide the tube 10 with an interior coating 60 of silver or other suitable material, over the area between the lines 61 and 62. This coating is electrically connected to the electrode 13 by a connection 63, and is therefore maintained at a positive potential. This coating, at a relatively high positive potential, creates an influence with respect to the cathode beam or ray to focus the same to a well defined spot on the anode 13—15.

The tube 10 is evacuated to the highest possible degree.

From the foregoing, it will be seen that an improved method of television transmission has been provided wherein an electrical image is developed from a light image, and a cathode ray developed and caused to scan the electrical image to influence a circuit in a suitable transmission system. In the embodiment of my invention disclosed, the electrical image is in the form of a relatively large number of electrostatic charges developed at uniformly spaced spots or regions over the surface of an electrode exposed on one side of and scanned by a cathode ray.

I claim as mv invention:—

1. In the art of television transmission, the method which comprises projecting an image to be transmitted upon a photoelectric cathode, accumulating the occurring electron emission from said cathode at regions spaced with respect to each other and disposed over an area commensurate with the image area, developing a cathode ray, scanning said regions with said ray to initiate a secondary electron emission from said regions, and absorbing the electrons of said secondary emission by an anode.

2. In a television transmission system the combination with means for transmitting picture signals of apparatus for developing such signals which comprises a source of cathode rays, a photoelectric cathode positioned remote from said source, a first and a second electrode element arranged in a plane substantially parallel to the photoelectric cathode and separated from each other and from the cathode and located between the cathode and the source, a plurality of pin-like elements carried by and distributed over the said electrode elements, said pin-like elements being spaced with respect to and insulated from each other and from the supporting electrodes, a third electrode element interposed between the pin-like elements and the ray source, and means for causing the ray developed to simultaneously scan the said third electrode and the area over which the pin-like elements are distributed.

3. In a cathode ray tube, a source of cathode rays at one end of the tube, a substantially uniform photoelectric surface perforate to the free flow of electrons therethrough at the other end of the tube, a pair of plate-like electrodes arranged in spaced parallel relationship to each other and to the photoelectric surface and each interposed between the photoelectric surface and the ray source, a plurality of pin-like electrodes insulatingly supported from each other and from the plate electrodes carried by the plate electrodes and protruding therebeyond toward the ray source to be scanned by the developed ray, and a mesh-like positive potential electrode located between the protruding pins and the ray source whereby the developed ray in reaching the pin-like electrodes passes through the mesh.

4. In cathode ray apparatus of the character described, a tube provided with a first electrode having a light-sensitive surface and being perforate to the free flow of electrons transversely through the same, a second electrode disposed in proximity to and in substantially parallel relation to said first electrode, said second electrode being imperforate to the free flow of electrons transversely through the same and comprising a plurality of electrically-conductive elements insulated from each other and from said second electrode and each exposed on both sides of the latter, and means for developing a ray of electrons directed at said second electrode, said second electrode being disposed between said means and said first electrode.

5. In a television transmission system, means for transmitting picture signals, means for developing picture signals and supplying the same to said first-named means; said second-named means comprising a cathode ray tube provided with first, second and third electrodes supported in spaced and substantially parallel relation to each other, said first electrode having a light-sensitive surface and being perforate to the free flow of electrons transversely through the same, said second electrode being disposed between said first and third electrodes, a plurality of electri-

cally-conductive elements forming part of said second electrode and each insulated from the same and from each other and each exposed on both sides of said second electrode, and means for developing a ray of electrons directed at said third electrode and the adjacent side of said second electrode, said third electrode being perforate to the free flow of electrons transversely through the same; and means connected to and maintaining said second and third electrodes at a relatively high positive potential with respect to the potential of said first electrode.

6. In combination with a television transmission system, an electron tube including at one end thereof a mesh-like screen member, photoelectric material covering one side of said mesh-like screen member onto which an optical image is adapted to be projected, means at the opposite end of the tube for producing an electron beam, a pair of plate-like electrodes positioned closely adjacent said mesh-like member and intermediate the mesh-like member and the electron beam source, and a plurality of collecting pin electrode members insulatingly supported between said plate like electrode members and each other and protruding therebeyond in the direction of the source of the electron ray whereby the electron ray when developed may be caused to scan said pin-like members.

7. In a cathode ray image transmitting tube, a source for developing an electron beam at one end of the tube, a mesh-like member positioned at the opposite end of the tube, said mesh-like member having a coating of photoelectric material upon one side thereof upon which an optical image is adapted to be projected to cause the emission of electrons, a plurality of electrode members positioned intermediate the mesh-like photoelectric member and the electron beam source, said members being adapted to have applied thereto voltages positive with respect to the electron source and to the photoelectrically coated mesh-like member, a plurality of pin-like members insulatingly supported between said plate-like electrode members and protruding therebeyond in the direction of the electron beam source for collecting the electrons emitted from the photoelectric mesh-like member under light activation, means for causing the developed electron beam to scan the said pin-like members to release the collected charges thereon to initiate electrical signals representative of the light image falling upon the photoelectric mesh-like member, and a screen electrode through which the developed electron beam is adapted to pass positioned intermediate the ends of the pin-like members and the electron beam source.

8. A television system comprising an electron tube, means for producing an electronic scanning beam within the tube, an electrode member comprising a plurality of electrically isolated sections each of substantially elemental size, a light sensitive surface, means for producing on one side of the isolated sections of the electrode in accordance with illumination of the light sensitive surface an electrostatic charge image, and means for moving the produced electronic scanning beam across the opposite side of the isolated sections of the electrode member to discharge the stored electrostatic charges and thereby produce signalling impulses proportional to the light initiating the electrostatic charges.

9. A television system comprising an electron tube, means for producing an electronic scanning beam within the tube, an electrode member comprising a plurality of electrically isolated sections each of substantially elemental size and having two exposed sides, a light sensitive surface, means for producing on one side of the isolated sections of the electrode in accordance with illumination of the light sensitive surface an electrostatic charge image, and means for moving the produced electronic scanning beam across the opposite side of the isolated sections of the electrode member to discharge the stored electrostatic charges and thereby produce signalling impulses proportional to the light initiating the electrostatic charges.

10. A television system comprising an electron tube, means for producing within the electron tube a cathode ray scanning beam, an electrode member comprising a plurality of electrically isolated sections each of substantially elemental size positioned in the path of the developed cathode ray beam, insulating means for supporting each of the plurality of electrically isolated sections of the electrode member, a light sensitive surface, means for projecting an image of a subject upon the light sensitive surface for releasing photoelectrons and producing thereby on one side of the isolated sections of the electrode member an electrostatic charge image of the light image, and means for moving the cathode ray beam across the opposite side of the isolated sections of the electrode to discharge the stored charges.

11. In a television system, means to produce an electrical current image of a light image, means to convert the electrical current image into an electrostatic charge image, and means for scanning the electrostatic charge image to produce signalling impulses.

12. In a television system, a photoelectric surface, means for illuminating the photoelectric surface with the light image of a subject of which a reproduction is to be produced at desired receiving points so that there is released from the photoelectric surface an electrical current image representative of the light image, means for producing from the resultant current image an electrostatic replica and means for scanning the electrostatic replica to produce signals representative of the original optical image.

13. In a television system an electron tube, a photoelectric surface positioned within the electron tube, means for focussing a light image upon the photoelectric surface to produce a current image representing the light image, means for converting the produced current image into an electrostatic image, means for developing a cathode ray beam, and means for moving the cathode ray beam for scanning the electrostatic image to produce signals for transmission representative of the original optical image.

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