July 10, 1956 P. T. FARNSWORTH 2,754,449

CATHODE RAY TUBE AND SYSTEM

Filed Nov. 25, 1950 4 Sheets-Sheet 1

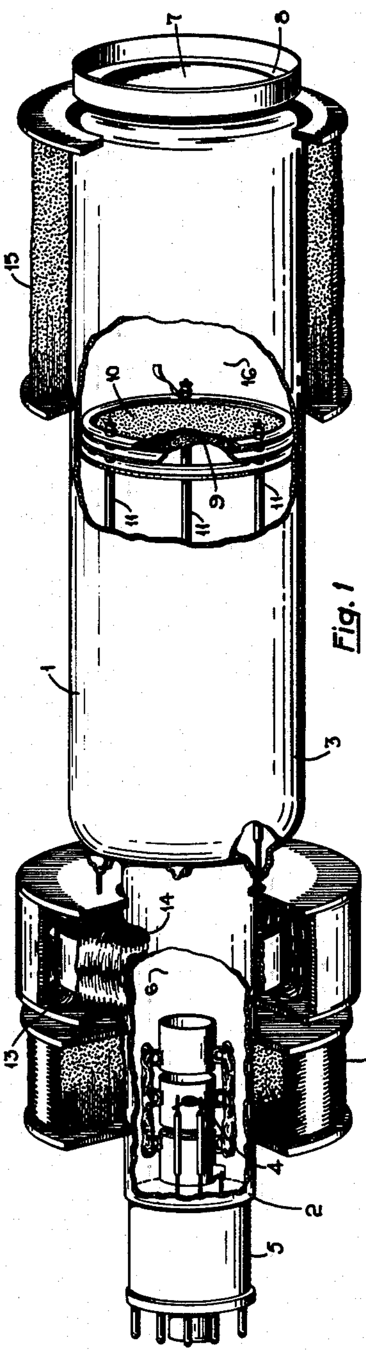

Fig. 1

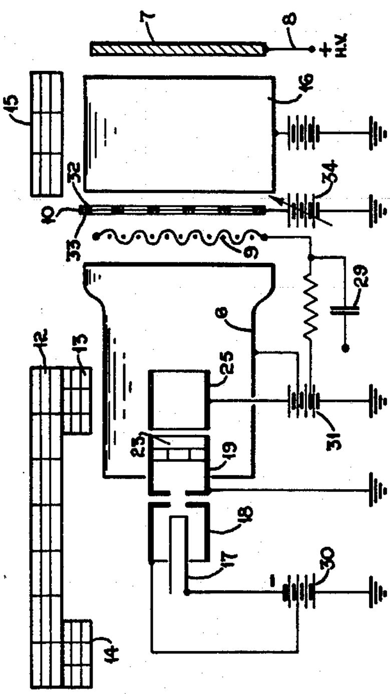

Fig. 3

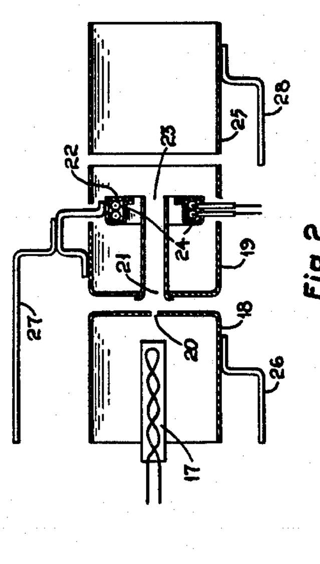

Fig. 2

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CATHODE RAY TUBE AND SYSTEM

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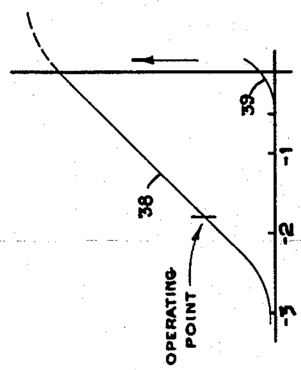

Fig. 5

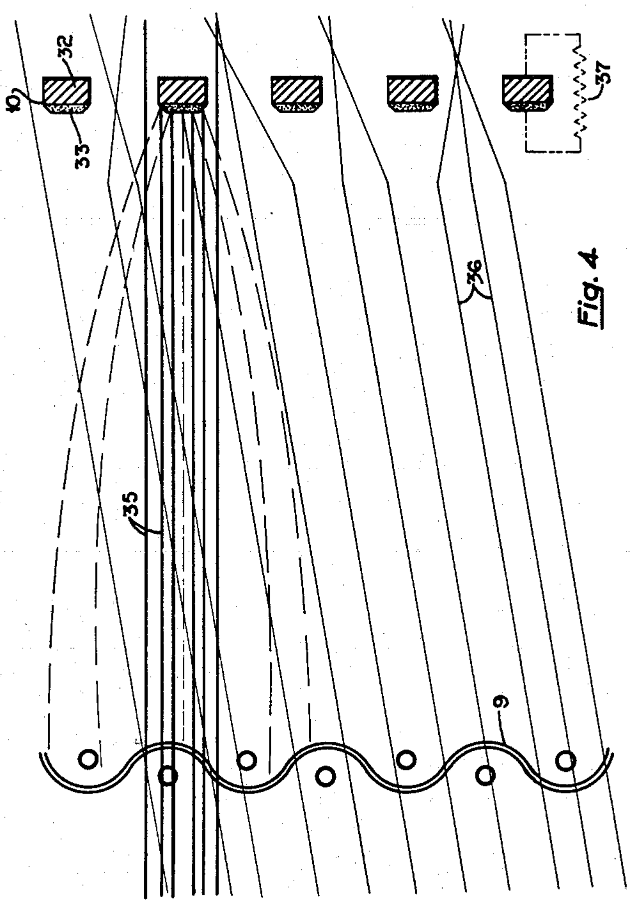

Fig. 4

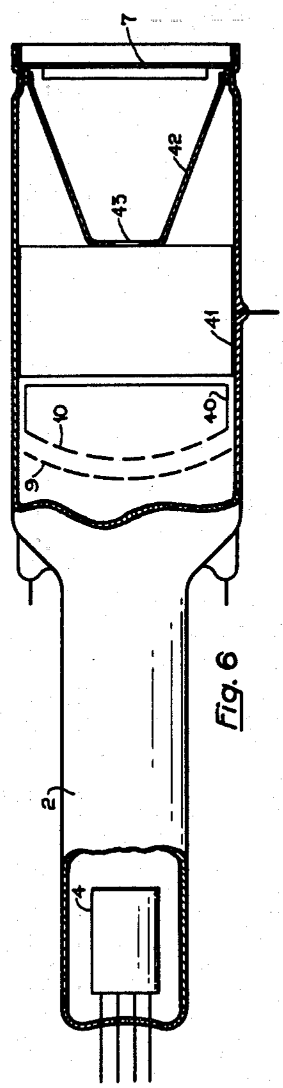

Fig. 6

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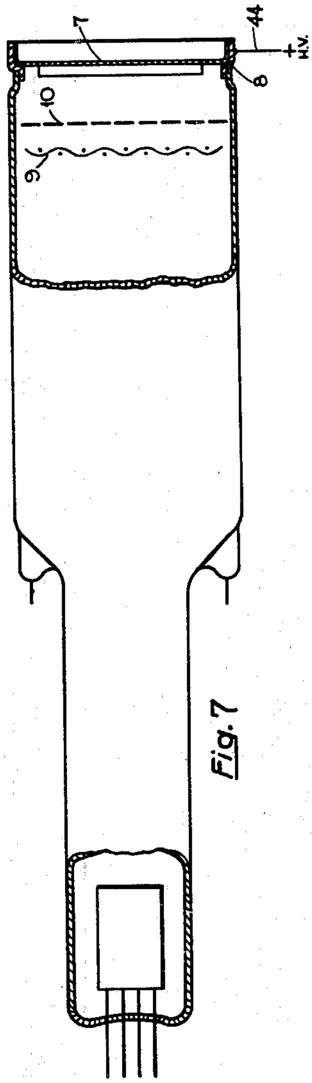

Fig. 7

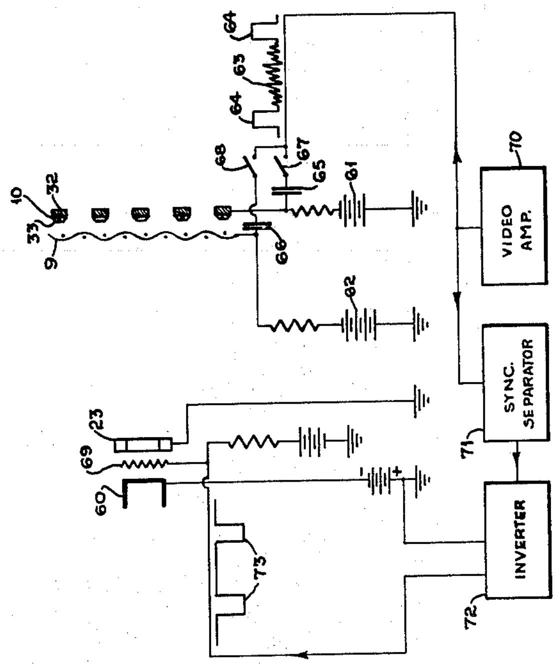

Fig. 9

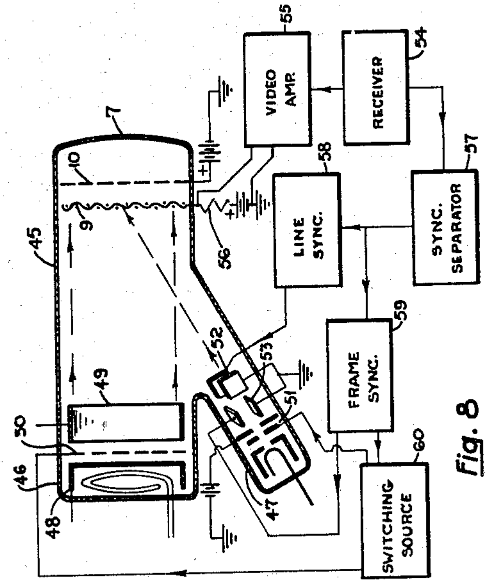

Fig. 8

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CATHODE RAY TUBE AND SYSTEM

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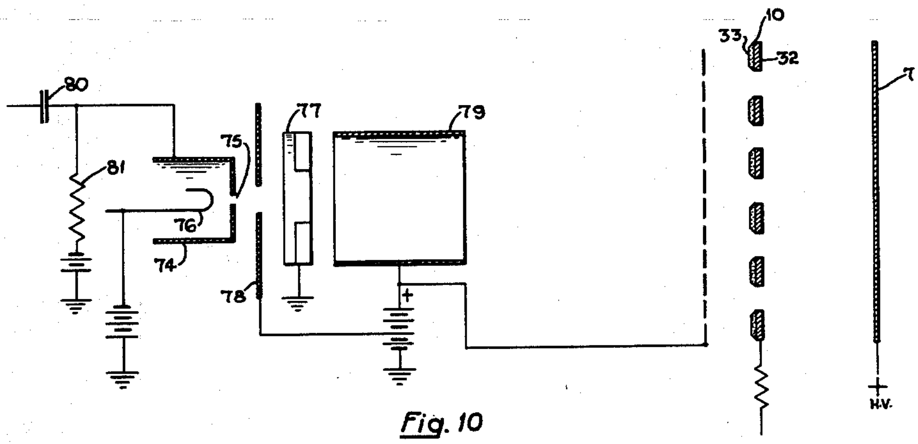

Fig. 10

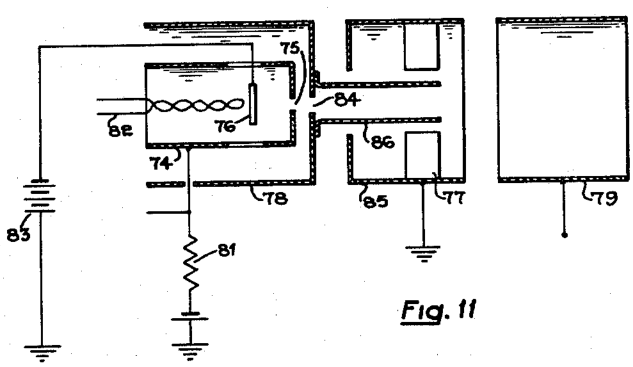

Fig. 11

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United States Patent Office

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CATHODE RAY TUBE AND SYSTEM

Philo T. Farnsworth, Fort Wayne, Ind., assignor to International Telephone and Telegraph Corporation, a corporation of Maryland

Application November 25, 1950, Serial No. 197,612

22 Claims. (Cl. 315—12)

This invention relates to cathode ray tubes and circuits and more particularly to such tubes and circuits which serve to provide an electron image amplification.

In my Patent No. 2,228,388, granted January 1, 1941, entitled "Cathode Ray Amplifier" a cathode ray tube with image amplification is disclosed. According to this patent, amplification of an electron image is accomplished by means of a cathode ray tube provided with two electron guns mounted to emit electrons in generally the same direction. In the path of the beams from these guns is mounted a perforate grid lattice or mesh structure consisting of a metal screen the wires of which are surrounded by insulation. An anode electrode maintained at a higher positive potential than the grid is mounted on the side of the grid structure away from the guns. One of the guns emits electrons at a slow velocity and focussed to cover all of the area of the grid structure. The other gun emits a beam of electrons focussed to cover only an elemental area of the grid structure, and of a sufficiently high velocity to cause greater than unity secondary emission from the insulating covering of the grid structure. If picture signals are applied to the second gun to vary the electron velocity or to the conductor of the grid structure to vary the potential difference of the second gun cathode relative thereto, while the beam from this gun is scanned over the grid structure, a positive charge image is produced on the screen varying in accordance with the picture signals. As a consequence, varying the flow of electrons from the first or flood gun through the grid structure will result producing in effect an amplified electron image. This may be applied to a viewing screen or other utilization device.

The system as described above requires a relatively high velocity in the second or scanning gun beam so that greater than unity secondary emission is assured. Furthermore, the degree of image charge that can be produced on the grid structure depends largely on the velocity of the scanning beam and the nature of the secondary emissive surface of the grid. The tube works only in the positive region serving only to reduce the number of electrons passing through the grid by attracting electrons to it by the positive charges. Moreover, leakage of the impressed charges must take place through the insulating coating on the grid structure conductors, this can be controlled only by the thickness of the insulator coating and the dielectric properties thereof.

Another proposed recording tube construction, based on the use of a storage screen previously proposed by applicant, is disclosed in the Proceedings of the I. R. E., July 1950, on page 740 et seq. In this construction a storage screen is provided of a metallic mesh coated on the surface facing away from an electron gun with a dielectric material. A combined collector-reflector electrode is positioned facing toward the insulating surface. In operation this collector reflector electrode is maintained at a negative potential during application of the image signals to the storage screen, while the screen supporting the dielectric material is at a positive potential. Electrons from the gun penetrate through the apertures of the screen and because of the reflecting electrode are caused to turn back and bombard the insulating coating knocking out secondary electrons so that a positive charge is made in the insulating coating, dependent upon the variations imparted to the beam by picture signals. Thus, as the beam is scanned a positive electrostatic image is stored on the insulating coating. For reproduction of this image the collector electrode is rendered positive so that the beam as it is scanned over the charged screen will vary in strength in accordance with the stored charge to reproduce the picture. In one arrangement proposed in this article the beam may be defocussed during this reproduction period so that the entire area of the storage screen will be covered by the beam and the picture may be reproduced in toto without scanning.

It will be noted in this instance that the electrostatic charge must be in a positive direction. Thus the effective control grid action is limited to the positive spectre. Furthermore, this construction requires that the insulating coating be arranged to face away from the electron gun requiring relatively complex control arrangement.

It is an object of this invention to provide an image amplifying tube of the type wherein an image charge is impressed upon a perforate grid structure by a scanning electron beam and to control the flow of electrons provided from a flood gun source through the apertures, wherein the grid structure is operated at all times in the negative region. The scanning gun beam may be of low velocity so as to build up a negative image charge on the grid, the grid comprising a conductive screen the surface toward the scanning beam source, only, being coated with a secondary emissive dielectric. In this case the conductive screeen is biased positively. If a scanning beam of higher velocity is used so that the dielectric tends to become more positive a negative bias is used on the conductive screen to preserve the negative region operating characteristics of the dielectric surface with respect to the flood gun cathode.

In accordance with a feature of my invention the gun structure may be energized so that two electron beams are provided, one of which is concentrated to cover an elemental area, and the other to cover a substantially greater or the entire area of a dielectric screen covered on the side toward the guns with a quartz for example. The conductor of this composite screen may be maintained at a potential slightly more positive than the flood gun cathode, the scanning or elemental gun cathode being negative with respect to the flood gun. If the scanning beam is made of higher velocity so that it causes secondary emission tending positively to charge the insulating surface, then the screen is maintained at a potential slightly negative with respect to the flood gun cathode. Preferably separate guns are used to produce the flood beam and scanning beam, either simultaneously or alternately operated. Alternatively, a single gun may be used with variable controls to change its operating characteristics alternately to serve as a scanning and flood gun.

Means is provided to scan the elemental beam over the composite screen or image storage grid in timed relation with the image signals to be stored and reproduced. At the same time variations in voltage corresponding with the image signals are produced between the scanning beam source and the image storage grid. Leakage of the stored charge takes place through the insulating coating and by surface leakage around the edges of this coating to the metal mesh, the latter being the predominate effect. The second, or flood gun, may be scanned over the area of the storage grid if the entire area is not covered by the beam. In view of the difficulty in obtaining a beam of uniform cross-section over the entire area, it may be preferable to use a beam which does not cover the entire surface and scan it to achieve greater uniformity of average coverage.

In order to provide a uniform virtual cathode or electron source adjacent the storage grid a collector electrode may be mounted, spaced from the insulated surface thereof. This collector electrode may be in the form of an open mesh, preferably coarser than the mesh of the storage screen. A predetermined small potential difference will exist between these elements dependent upon biasing potentials and the electrons introduced into the space by the guns.

The utilization device for the electron image formed by electrons passing through the storage may be a luminescent screen, such as a fluorescent screen. Since the electrons passing through the control storage screen mesh cover a substantial area of the luminescent screen a greater average brightness is obtained without excessively high current densities than when a beam of elemental cross section is used. Accordingly a brighter image suitable for projection may be readily obtained. Moreover, a relatively small storage charge controls, a much larger electron flow from the virtual cathode, resulting in electron amplification.

The above and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a perspective view partly broken away, showing an image tube in accordance with this invention;

Fig. 2 is a diagrammatic illustration of a cathode gun structure as shown in Fig. 1;

Fig. 3 is a schematic circuit diagram for a tube such as shown in Fig. 1;

Fig. 4 is a schematic illustration showing the operation of the system illustrated in Fig. 3;

Fig. 5 is a typical characteristic operating curve for the structure of Fig. 3;

Figs. 6 and 7 are diagrams of alternative tube constructions to that illustrated in Fig. 1;

Fig. 8 is a schematic circuit digaram illustrating a system for alternate operation of the flood gun and scanning gun in accordance with my invention.

Fig. 9 is a schematic diagram of a modified arrangement for operation of the electron guns alternately similar to showing of Fig. 8;

Fig. 10 is a schematic diagram of a modified cathode ray tube in accordance with my invention, and

Fig. 11 is a detailed diagram of the cathode gun structure used in the circuit of Fig. 10.

Turning now to the drawings, a typical tube in accordance with this invention, as constructed for test purposes is illustrated. The tube comprises an envelope **1** having a portion **2** of relatively small diameter and another portion **3** of larger diameter. At one end of the envelope is mounted an electron gun assembly **4** for providing two electron beams, one of which is concentrated to provide coverage of an elemental area on an image storage screen, the other providing a flood of electrons over a substantial area thereof. Connections for the various gun electrodes are brought out through base **5**. A conductive coating **6** is provided internally of the envelope portion **2** for the purposes of beam control as generally provided in cathode ray tubes. At the opposite end of the envelope **1** is provided an image reproducing screen **7** which may, for example, be a fluorescent screen having a coating of phosphor material which will fluoresce under the impact of the electrons thereon. A "Covar" ring **8** serves to seal the fluorescent screen **7** to the body portion **3** of the envelope. A fine open mesh screen **9** is mounted substantially mid-way between the ends of portion **3**. This screen or mesh may be termed as the collector electrode and is conveniently made by an electro-plating method. This screen may be, for example,

approximately 600 mesh per inch screen. Mounted within the tube and spaced between screen **9** and fluorescent screen **7** is provided the image storage mesh or screen **10**. This perforate screen may have 1,000,000 perforations or more per square inch. In an actual tube construction a 1,000 mesh screen was used in which the openings constituted approximately 60% of the screen surface. On the surface of screen **10** facing the collector electrode **9** is provided a thin film of insulating material which may be coated thereon, by evaporation. This may be of any desirable dielectric, for example quartz. The thickness of the dielectric film is determined by the requirement that the electro-static capacity be relatively high, of the order of $.7\times10^{-9}$ farads to 7×10^{-9} farads per square cm. This will provide a thickness of quartz of 5 microns to .5 micron (5.0×10^{-4} cm. to 0.5×10^{-4} cm.). These elements **9** and **10** are supported by support and lead out conductors **11** from the shoulder between portions **2** and **3** of the envelope. In order to control the focusing of the beams onto the screens **9** and **10** and the scanning of the beams over these screens magnetic focusing coil **12** and deflection coils **13**, **14** may be provided. An additional focusing coil **15** may be provided about the envelope portion **3** between the electrode **10** and the fluorescent screen **7**. The inner surface of this portion of the envelope is also preferably provided with a conductive coating **16** for the same purposes as the coating **6**.

Since it is desired that the gun provide two beams one of which is concentrated in an elemental area and the other of which covers a larger area, a typical electron gun construction for this purpose is illustrated in Fig. 2. For the elemental beam gun there is provided an indirectly heated cathode **17** in front of which is mounted an accelerating electrode **18** and a focussing electrode **19**. Elements **18** and **19** are provided with narrow apertures **20** and **21** through which the electron beam from cathode **17** is directed. Mounted within the shell of element **19** is provided a second indirectly heated cathode **22** which may consist of a coated annulus having an opening **23** aligned with apertures **20** and **21** so that the narrow beam from the cathode **17** may pass through the center. A heating filament **24** may be provided for heating the cathode **23** and an accelerating electrode **25** is provided to direct the emission from cathode **22** outwardly from the gun. Output leads for electrodes **18**, **19** and **25** are shown at **26**, **27** and **28** respectively. Electrons from cathode **17** will be focussed into a very narrow beam which may be restricted to cover an elemental picture area. The electrons from cathode **22** however, will be projected so as to cover a relatively large area in the space between screens **9** and **10**.

In Fig. 3 is shown a typical circuit arrangement for operation of a tube such as shown in Figs. 1 and 2. Input video frequency signals may be applied over condenser **29** to collector electrode **9**. A negative biasing battery **30** may be connected to the gun cathode. Electrode **19** may be at ground potential as shown. The cathode and the electron gun portions **17** and **18** are negative with respect to ground and will produce a relatively low velocity elemental electron beam. The second cathode **23** will, be also at ground potential. Electrode **25** is maintained at a potential positive with respect to cathode **19** by means of the battery **31**. The internal wall coating **6** of the tube is maintained at a positive potential less than that of electrode **25** for the purpose of picking up stray electrons. Electrode **9** is maintained at a potential somewhat positive with respect to cathode **23** but of lower positive potential than elements **25** or **6**. Storage electrode **10** which consists of the metal grid portion **32** and insulated coating **33** has the metallic element maintained at a potential slightly positive with respect to the potential of element **9** by means of the adjustable source shown as battery **34**. This source may be made adjustable to provide any desired potential difference between these two electrodes for the purpose of controlling the field therebetween. A positive voltage is applied to the inner wall coating 16. Alternatively, an additional electrode positively polarised may be used to accelerate any electrons passing through the storage or control screen 10. The various focussing and deflecting coils are diagrammatically illustrated at 12, 13, 14 and 15.

In order more fully to explain the operation of this tube reference is made to Fig. 4 along with Fig. 3. In Fig. 4 is illustrated an enlarged showing of a part of the storage control electrode 10, having the conducting and insulating portions 32 and 33 respectively, and a portion of the collector screen electrode 9 in Fig. 3. The control or scanning beam is indicated by the heavy lines 35 and the electrons from the flood gun are indicated by the light slanting lines 36. We may first consider the action of the control or scanning beam 35 as though the flood beam 36 were turned off. As the beam 35 is scanned over the electrode 10 a charge will be applied to the coating 33. It will be evident that the charge which may be built up on this insulator will depend in part on the voltage difference between electrode 9 and 10. It will also be dependent upon the leakage between the surface of the dielectric and the metal base. This leakage resistance is symbolically indicated by dotted resistor 37. The time constant of the composite screen may be defined as R1,C1 where R1 is the leakage resistance through 37 and C1 is the capacitance between the two surfaces of 33. For good dielectrics the leakage through the coating is small with respect to the surface leakage and can be neglected. The proper value of this time constant varies for different applications, and might be for example about .1 sec. for television.

It may be assumed first that the control beam 35 strikes the screen 33 with a velocity sufficient to eject more than one secondary per primary electron. When this control beam is bombarding an insulating element, current flows into or out of the element until the voltage of the element is changed by just a required amount to make the current into the element including leakage current, equal to the current out. Thus a balance of current is obtained for some definite value of potential difference between the insulator and the collector. The collector electrode 9 will always be maintained somewhat more positive than the insulator element 33. Some of the control beam electrons will pass through the openings in the mesh during scanning but this effect is negligible and has no appreciable effect on the image produced on the fluorescent screen.

An idea of the approximate value of potential difference between the collector 9 and the insulating element 33 for a particular value of beam current 35 may be had by applying Langmuir's three-halves-power law. Since the secondary electrons which leave the insulators diverge as they leave the element the geometry of the electrostatic field may be assumed to lie somewhere between that of "concentric spheres" and that of parallel plane geometry. Simple calculations based on both types of geometry indicate:

(1) That the equilibrium potential difference E between an insulating element and the collector screen is given by the relationship

$$E=\frac{A}{i^{2/3}} \qquad (1)$$

where i is the current into and out of the insulating element. That is, it is the component of control beam current which strikes the insulating element.

(2) The constant A in Equation 1 is determined by the geometry of the structure.

(3) For a current i of 5 microamps the equilibrium potential E appears to lie between 5 and 10 volts.

It may be assumed now that the beam current is such that a constant potential of exactly 5 volts exists between the equilibrium potential of the insulator and the collector. If the potential of the collector, is varied by the video voltages as the control beam, is scanned over the insulating film in a scanning raster pattern, a charge pattern will be built up which is an electrostatic image of the picture defined by the input video signals. By making the electrostatic capacity of the insulating film 33 to the metal support 32 of approximately the correct value, about 10^{-8} farads, the charges will approach closely to their equilibrium value of 5 volts. Under these conditions the insulator element which is being bombarded at any given instant by the control beam will assume a potential 5 volts negative with respect to the collector voltage at that instant.

The flood gun, energized from the cathode 22, establishes a space current charge immediately adjacent the perforations of the insulated storage grid 10, thus electrons from this space charge produced by beam 36 will flow through the apertures of electrode 10 in an amount dependent upon the picture charge voltages established over this surface. If the electron or current flow through the apertures of the insulated grid 10 is plotted against the potential of the insulator element 33 a characteristic curve 38 as shown in Fig. 5 will be obtained. It should be noted, curve 39, that the flood gun current will be collected by the insulator elements when the element is negative, by less than about 0.5 volt. This collection of electrons can be avoided by confining the swing of the grid elements 10 to voltages more negative than —.5 volt. It appears desirable to make the operating part of the characteristic 38 illustrated in Fig. 5 as long as possible. The D. C. voltage on the base 32 of electrode 10 should be as high as possible without drawing electrons from the insulator to it. This potential may be, for example, 5–20 volts positive with respect to the voltage of collector electrode 9.

The electron beam 35 which is used to control the charge distribution of the insulating surface 33 must be focussed into a spot of element size, for example, .002 inch (.005 cm.) in diameter. The beam current is relatively small for example 10 microamps, so this required accuracy of focus is readily obtainable. The focussing of this beam is conveniently obtained by using a coil surrounding the neck of the tube.

The function of the flood gun is to establish a virtual cathode source of electrons between the collector screen and the perforated insulator on electrode 10. The area covered by the virtual cathode should extend over a substantial part of the area of the insulator. The flood beam may be scanned over the insulator simultaneously with the control beam. This serves to control the uniformity of the resulting final image. It is unnecessary however that the flood gun scan the insulator in the same sequence as the control beam nor even that it be deflected at all. In some applications, for example, it may be advantageous to scan the flood beam in one direction only.

It may be useful in some instance to have the extent of area covered by the flood beam controllable. Referring to Fig. 2, the actual area of the screen coverage may be changed by changing the size of cathode 22, the geometry of the gun structure or the voltages employed. In a given tube the size of the flood beam may be changed either by using a different focussing coil system or by changing the order of the magnetic focus used. A wide variation of gun structures may be devised, the structure shown in Fig. 2 being only considered as an example.

While I have described above one method of establishing the electrostatic charge image on the dielectric film of electrode 10 there are other alternative methods which may be used. In one other such method the control beam source cathode 17 may be operated only slightly more negative (—15 to —20 volts) than the flood cathode 22. The electron beam 35 then strikes the insulator with a velocity which is insufficient to eject more than one secondary per primary electron. The control beam, therefore, always imparts a negative charge on the insulating element. This control beam may be modulated with the video signals preferably by varying the potential on the cathode **17**. A negative charge image pattern is thus placed on the insulator. This charge will leak off, at least in part between scansions, to the backing plate **35**. The time required for such leak-off is directly proportional to R1, C1, and inversely to the potential difference between the insulator **33** and its support **32**. In this type of operation the insulator backing plate **32** is operated normally slightly positive with respect to the flood cathode. The value of this positive voltage determines the average brightness of the image.

A third method of operation may be used which is similar to the second method described above except that the control beam voltage of cathode **17** is operated sufficiently more negative than the flood cathode to permit a secondary emission ratio at the insulator greater than unity. The beam then charges the insulator element positively instead of imparting a negative charge and the polarity of the electrostatic image is reversed. In this case it is necessary to maintain the backing plate **32** at a slightly negative potential with respect to the flood cathode **23**. The charge pattern, however, leaks off to the backing plate between scansions in a manner similar to that of the second method described. When the insulator backing plate is maintained at a negative potential with respect to the flood cathode, it becomes necessary to maintain a much larger positive potential on the wall coating **16** to pull electrons through the grid apertures.

The conversion of the charge pattern into an electron image by drawing electrons from the virtual cathode through the apertures is the same for both of these methods of applying the electrostatic charge as was described in the first instance.

While the tube structure is described above as contemplating the use of electromagnetic focussing of the electron images, it is clear that other types of focussing may be used if desired. In Fig. 6, is indicated a tube structure similar to that of Fig. 1 wherein electrostatic focussing of the amplified electron image is used in place of the electromagnetic focussing. In this case collector electrode **9** and storage electrode **10** are preferably made concave toward the fluorescent screen **7**. An extension **40** is made to the backing part of electrode **10**. Wall coating **41** is at a higher positive potential than **40**, and a still higher positive potential is applied to an electrode **42** provided with a central aperture **43**. As is well known in the art this electrode arrangement, with properly adjusted voltages, will focus an inverted electron image from screen **10** onto the luminescent screen **7**.

A simplified version of the electrostatic focussing arrangement is shown in Fig. 7. In this figure the electrostatic focussing constitutes simply an arrangement of the fluorescent screen **7** with relatively close spacing to the storage electrode **10** so that the amplified electron image does not have sufficient time to spread out after passing through the apertures. Thus the image will be properly impressed on fluorescent screen **7**. If desired a positive potential may be applied to ring **8** as shown at **44**.

In all of the system so far described a common dual gun together with arrangements for simultaneously applying energy to the control gun and the flood gun have been shown. It is clear however that applicant's system may be used with arrangements wherein the flood gun and the screen gun are alternately energised. A schematic circuit arrangement for a tube utilizing this type of operation is illustrated in Fig. 8. In this figure an envelope **45** is provided with two branches at one end as indicated at **46** and **47**. In **46** is arranged a flood gun which may comprise an indirectly heated cathode **48**, an anode **49** and a control grid electrode **50**. The flood gun is so arranged as to project the beam over all or a substantial portion of electrodes **9** and **10**. In branch **46** of the envelope is provided the normal scanning gun structure having in addition a switching control electrode **51**. Electrostatic plates **52**, **53** are provided to furnish the normal line and frame scanning raster for the image signals. The received signals are applied to a receiver **54** and from this receiver the video signals may be applied through video amplifier **55** and resistor **56**, to the collector electrode **9**. The synchronizing signals are applied through synchronizing signal separator **57** to the line and frame synchronizing generators shown at **58** and **59**. An output signal from synchronizing generator **59** may be applied to the switching source **60** so as alternately to render the scanning gun and flood gun operative. The scanning gun will have its grid **51** rendered positive for a period sufficient to scan the entire raster and produce the electrostatic charge on electrode **10**. Thereafter grid **51** will be biassed to cut off and grid **50** will be made positive so that the flood gun may project electrons through electrode **10** onto image screen **7**.

Turning now to Fig. 9, there is illustrated schematically a part of the tube structure and circuit showing an alternative operating system similar in some respects to that shown in Fig. 8. In this arrangement the scanning gun **60** and the flood gun **23** are shown in axial alignment as was shown in connection with Fig. 2. The collector screen **9** and the image storage screen **10** are arranged in the same manner as previously described. However, the metallic backing portion **32** of screen **10** is maintained negative by battery source **61** and similarly screen **9** may be maintained negative by battery source **62**. The input video signals shown at **63** together with the synchronizing pulses **64** may be applied over condenser **65** to the metallic backing of electrode **10** and over a condenser **66** to electrode **9**. Switches **67** and **68** are provided so that the signal may be applied over one or both of electrodes **9** and **10**. Batteries **61** and **62** are of such a value that the electrodes **9** and **10** are normally maintained sufficiently negative to prevent electrons from flood gun **23** from reaching these electrodes. At the same time, a control grid **69** in front of cathode **60** is maintained at a positive potential so as to permit the electrons from gun **60** to impinge upon the insulator coating **33** at electrode **10** and to knock out secondary electrons therefrom so that they tend to go in a positive direction in accordance with the variation in picture signals **63** as applied to the screen. The output signals from video amplifier **70** may be applied through the synchronizing signal separator and an inverter **72** to grid **69**. The separated inverted signals **73** are of sufficient negative amplitude as to bias grid **69** to cut-off. At the same time, the synchronizing pulses **64** applied in positive polarity to electrodes **10** and **9** are of sufficient positive value to overcome the effect of the negative biasing batteries thus permitting the electrons from the flood gun to flow through the apertures of the screens to the reproducing device. If it is desired, the synchronizing pulses may be applied to the cathode of flood gun **60** instead of to a control grid. In this case positive pulses will have to be applied to effect the desired cut-off. The biasing potential on electrode **10** is such that even though secondary emission occurs the insulating covering **33** is still operated in the negative region so that no grid current is drawn. With this arrangement modulation may be applied directly to the storage screen instead of to other electrodes as previously described. It will also be noted that because of the potentials used, the time constant of the storage screen is not critical so long as it is not short and a leakage discharge of the storage coating occurs.

In Fig. 10 is shown a schematic diagram of an alternative construction and circuit arrangement in accordance with this invention which has been found to provide good performance. In this arrangement scanning beam cathode **74** is provided with a narrow aperture **75** and an additional cathode **76** is mounted within the cathode **74** adjacent this aperture. Cathodes **74** and **76** may be heated by the same heating filament. A third cathode furnishing the flood gun electrons is shown at **77**. The accelerating electrode **78** is provided for cathodes **74** and **76** and another accelerating electrode 79 is furnished for all of these guns. The collector screen 9 is preferably maintained at substantially the same potential as electrode 79. Cathode 76 is maintained sufficiently negative with respect to cathode 77 so that it will always eject more than one secondary electron from the covering 33 of electrode 10 for each electron impinging thereon. Cathode 74 is maintained only slightly more negative than the flood gun cathode 77 so that it will contribute a negative charge to the insulator covering 33. The flood gun cathode may be operated at ground potential.

To explain the principle of operation of this system it may be considered first that the insulator cover 33 is initially charged to a negative potential of a few volts with respect to ground. Under these conditions only the electrons from cathode 76 can strike the insulator. Since the electrons from the cathode 76 strike with sufficient velocity to eject more than one secondary per primary electron and since these secondary electrons will be drawn away from the insulator to the collector screen grid 9, the insulator will begin to charge toward a positive direction and will continue to do so until it has reached a point substantially equal to the instantaneous potential of the cathode 74. When the potential of the insulator reaches that of cathode 74 electrons from this cathode will impinge upon the insulator and will prevent it from becoming more positive than the instantaneous voltage of this cathode. The potential of cathode 74 however is not constant but varies with the input video signals applied over condenser 80 and resistor 81. Thus as the beam from cathodes 74 and 76 is secured over the screen the charge pattern on the insulator will be changed each scansion to correspond to the instantaneous variations in the video scanning. It will be evident that the beam current from cathode 74, should be greater than the actual current which flows out of the insulator as a result of the impact from the cathode 76, including the leakage current. This condition will generally be met by making the beam from cathode 74 at least as great as that from cathode 76. It will thus be seen that an image charge will be placed on coating 33 which will control the flow of electrons from cathode 77 onto the utilisation circuit 7 in accordance with the image signals. Here again the time constant of the electrode 10 is not critical as long as it is not so short that excessive leakage will occur.

In Fig. 11 an actual constructive arrangement of the electron gun assembly of Fig. 10 is shown. Cathode 74 is made in the form of a sleeve having its end provided with aperture 75 and coated with a properly emissive substance. Cathode 76 is mounted inside of the sleeve of cathode 74 adjacent aperture 75 and a common heating filament 82 is provided to heat this assembly. Preferably a negative voltage of from 30–50 volts is applied to cathode 76 from the battery 83 and a battery having a negative potential for example, of 1.5 volts, is connected to cathode 74. The anode of insulating electrode 78 may be in the form of a sleeve shielding the cathode assembly 74 and 76 having an aperture 84 aligned with aperture 75. The flood cathode 77 may be mounted within a shell 85 maintained substantially at ground potential while anode 79 may be maintained at a positive potential of 100–300 volts. In order to prevent interaction between the electron beams from cathodes 74 and 76 an extension sleeve 86 may be provided extending from anode 78 to the outer edge of flood cathode 77.

It will be recognised from the foregoing description that a number of particular features are incorporated in applicant's invention which are quite different from any previously known system. It will be evident that in all of the methods of operation described the flood electrons never actually strike the insulating coating on the storage control grid as under every condition of operation this grid is maintained negative. This type of operation is unique in the present tube so far as applicant is aware.

It is clear that while certain embodiments of the invention have been described with a degree of particularity many modifications and variations thereof will occur to those skilled in the art.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

What is claimed is:

1. In a cathode ray tube system a perforate electrostatic storage electrode including a conductor covered on one surface only, with a dielectric material, means for providing an electron cloud serving as a virtual cathode adjacent said dielectric surface of said electrode, means for establishing a predetermined potential on said conductor, means for establishing a mean negative potential bias on said surface of a magnitude such that the surface is always to some degree negative with respect to said virtual cathode during operation, means for applying an electrostatic potential pattern on said dielectric which is negative with respect to said virtual cathode even at its most positive excursion, means for applying a potential field to attract electrons from said virtual cathode through the perforations in said electrode to produce an electron image corresponding with said pattern, and a utilization device for said electron image.

2. A cathode ray tube system comprising a cathode ray tube having a first and a second cathode ray beam source, a perforate screen mounted in said tube transversely of said beam, said screen having an insulating covering on its surface facing said beam sources, means for focusing said first beam to cover an elemental area of said screen, means for establishing a mean negative potential bias on said surface of a magnitude such that said surface is always to some degree negative with respect to said second cathode ray beam source, means for scanning said first beam over said screen to produce an electrostatic charge on said insulating surface, said charges being negative with respect to said second cathode ray beam source at their most positive excursion, means for modifying the action of said first beam and screen in accordance with a signal in synchronism with the scanning to cause said charge to be an electrostatic image charge of said signal on said screen, means for producing a virtual cathode adjacent the insulator surface of said screen in response to electrons from said second source, and means for attracting electrons from said virtual cathode through the perforations of said screen to produce an electron image corresponding to said electrostatic charge image.

3. A cathode ray tube according to claim 2, wherein said first beam source comprises a first emitter means for maintaining said emitter slightly negative with respect to said second source, said first emitter having an aperture in one end, a second emitter positioned to emit electrons through said aperture, and means for maintaining said second emitter negative with respect to said first emitter, whereby it will cause secondary emission upon impinging onto said insulated covering, and said means for modifying the action of said beams comprises means for applying image signal voltage variations to said first emitter.

4. A cathode ray tube system comprising an envelope, a perforated conductive screen positioned within said envelope, an insulating coating on one surface of said screen, a first electron beam source directed toward said surface, focusing means for focusing said first electron beam onto an elemental area of said surface, scanning means for scanning said first electron beam over said surface, means for establishing an electrostatic image signal charge on said insulated coating in response to applied signals, means for establishing a virtual electron

source adjacent said surface including a second electron source directed toward said insulated surface for providing a second electron beam emission covering a substantial area of said surface, means for establishing a mean negative potential bias on said surface of a magnitude such that said surface is always to some degree negative with respect to said virtual electron source during operation, means for attracting electrons from said virtual source through the perforations of said screen whereby an electron image is established through the action of said charge, and a utilization device for said electron image.

5. A cathode ray tube system comprising an envelope, a perforated conductive screen positioned within said envelope, an insulating coating on one surface of said screen, a first electron beam source directed toward said surface, focusing means for focusing said first electron beam onto an elemental area of said surface, scanning means for scanning said first electron beam over said surface, means for establishing an electrostatic image signal charge on said insulated coating in response to applied signals, means for establishing a virtual electron source adjacent said surface including a second electron source directed toward said insulated surface for providing a second electron beam emission covering a substantial area of said surface, said virtual electron source being positive with respect to said electrostatic charge, means for attracting electrons from said virtual source through the perforating of said screen whereby an electron image is established through the action of said charge, and a utilization device for said electron image, said scanning means being positioned to also scan said second beam over said surface.

6. A system according to claim 4, further comprising means for alternately rendering said first and second sources effective.

7. A cathode ray tube according to claim 6, wherein said means for establishing the image signal charge comprises means for normally maintaining said conductive screen negative with respect to said second source and positive with respect to said first source, and means for applying image signals to said screen, and said means for alternately rendering said first and second sources effective comprises means responsive to received synchronizing signals for rendering said conductive screen positive with respect to said second source, and means responsive to said synchronizing signals for blocking emission from said first source.

8. A system according to claim 4, wherein said utilization device comprises a luminescent screen and means for accelerating said electrons passed through said perforations toward said screen.

9. A system according to claim 4, wherein said means for establishing the image signal charge comprises means for modulating said first electron beam.

10. A system according to claim 4, further comprising a collector screen mounted between said storage screen and said guns.

11. A system according to claim 10, wherein said means for establishing the image signal charge comprises means for varying the voltage of said collector screen in response to image signals.

12. A cathode ray tube system comprising an envelope, a perforated conductive screen positioned within said envelope and provided with a reference voltage terminal extending outside said envelope, an insulating covering on one surface of said screen, a collector conductive screen mounted within said envelope facing said insulating covering and provided with a terminal extending outside said envelope, a first electron beam source directed toward said surface, focusing means for focusing said electron beam onto an elemental area of said surface, scanning means for scanning said electron beam over said surface, whereby an electrostatic image charge is established over said surface in response to the scanning of said electron beam, a second electron source directed toward said insulated surface to cover a substantial area of said surface, whereby an electron space charge between said surface and said collector screen is produced, means for establishing a mean negative potential bias on said surface of a magnitude such that said surface is always to some degree negative with respect to said second electron source during operation; means for establishing a variation in said electro-static image charge in response to applied signals within the limits that said charge is always to some degree negative with respect to said second electron source, whereby an amplified electron image is produced in the space beyond said perforate conductive screen by electrons passed through the perforations, and a utilization device for said amplified electron image.

13. A cathode ray tube system comprising an envelope, a perforated screen having a predetermined number of perforations per unit positioned with said envelope and provided with a reference voltage terminal extending outside said envelope, an insulating covering on one surface of said screen, a collector conductive screen having a different number of perforations per unit area than said first screen mounted within said envelope facing the covering of said first screen and provided with a terminal extending outside said envelope, a first electron beam directed through said control screen toward said surface, focusing means for focusing said electron beam onto an elemental area of said surface, scanning means for scanning said electron beam over said surface whereby an electrostatic image charge is established over said surface in response to the scanning of said electron beam, a second electron source directed through said control screen toward said insulated surface for providing an electron emission covering a substantial area of said surface, to produce an electron space current charge between said surface and said control screen, means for establishing a mean negative potential bias on said surface of a magnitude such that said surface is always to some degree negative with respect to said second electron source during operation, means for producing a variation in said electrostatic image charge in response to applied signals within the limits that said charge is always to some degree negative with respect to said second electron source, whereby an amplified electron image is established in the space beyond said perforate conductive screen by electrons passed through the perforations, and a utilization device for said amplified electron image.

14. In a cathode ray tube system having a perforate conductive electrode covered on one side only, with a dielectric material, a method of operation comprising providing a virtual cathode source adjacent said dielectric surface, establishing a negative mean operating potential on said surface which is of a magnitude sufficient to maintain said surface negative to some degree throughout the entire range of operation of said system, applying a potential pattern which is at all times negative to some degree with respect to said virtual cathode source to said dielectric, and providing a potential field to attract electrons from said virtual cathode source through perforations in said electrode, to produce an electron image.

15. A method of operation according to claim 14, wherein an electron beam of elemental area is provided, the method of applying said potential pattern which comprises scanning said beam over said surface and varying the current of said beam in accordance with said potential pattern.

16. A method of operation according to claim 14, wherein an electron beam of elemental area is provided directed toward said surface and a collector screen is positioned between said source and said surface, the method of applying said potential pattern which comprises scanning said beam over said surface and simultaneously varying the potential on said screen in accordance with said potential pattern.

17. A method according to claim 16 further comprising maintaining said electrode positive with respect to the electron beam source.

18. A method according to claim 17, further comprising giving to said electron beam a velocity insufficient to cause secondary emission from said surface.

19. A method according to claim 17, further comprising giving to said electron beam a velocity sufficient to cause emission of electrons from said surface.

20. A method of operation according to claim 14, wherein an electron beam of elemental area is provided directed toward said surface, and an electron beam of relatively large cross-section and of lower velocity is directed toward said surface to provide said virtual source, the step including alternately rendering beams from said sources effective.

21. A method according to claim 20, wherein the method of applying said potential pattern to said screen, comprises scanning said elemental beam over said surface, and simultaneously varying the potential on said electrode in accordance with said potential pattern.

22. A method according to claim 20, wherein there is provided a third electron beam within the beam of elemental area, comprising normally maintaining said electrode at a negative potential sufficient to prevent impingement of said beam of large cross-section, giving to said third beam sufficient velocity to cause secondary emission from said surface, giving to said elemental area beam insufficient velocity to produce secondary emission, and varying the potential of said elemental beam in accordance with said image potential pattern.

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