

April 28, 1942.

A. N. GOLDSMITH

2,280,946

THERMAL OPTICAL IMAGE REPRODUCING SYSTEM

Filed Nov. 1, 1939

3 Sheets-Sheet 1

Fig. 1

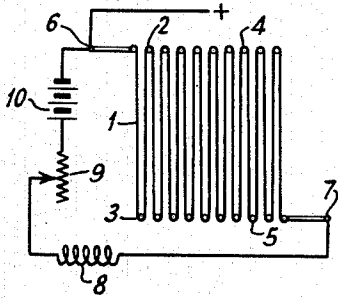


Fig. 2

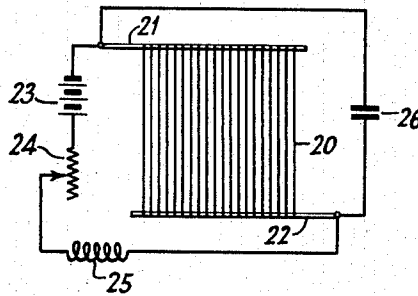


Fig. 3

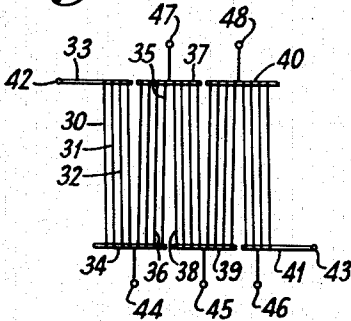


Fig. 4

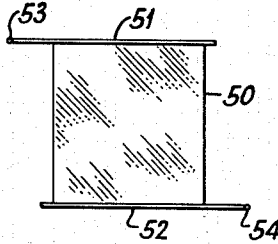


Fig. 5

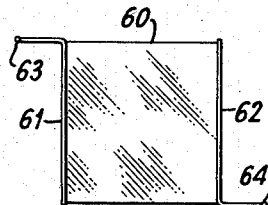


Fig. 6

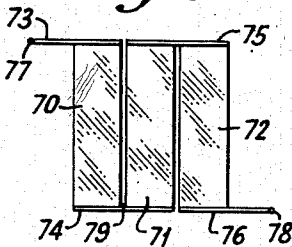


Fig. 7

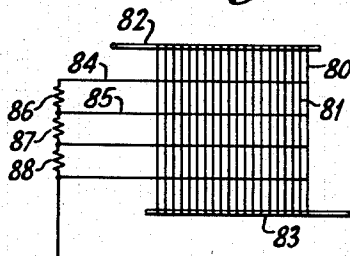
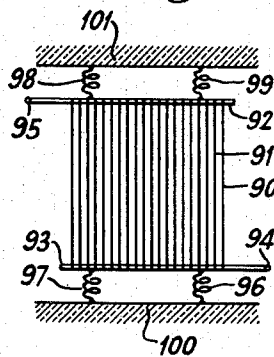


Fig. 8



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Fig. 10

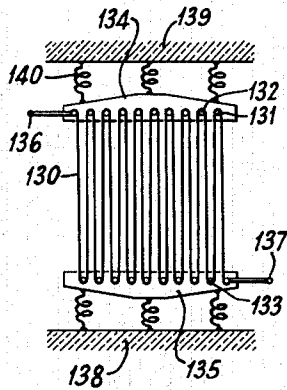


Fig. 11

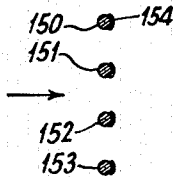


Fig. 12



Fig. 13

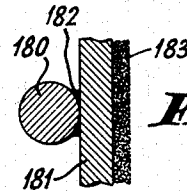
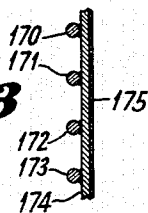


Fig. 14

Fig. 15

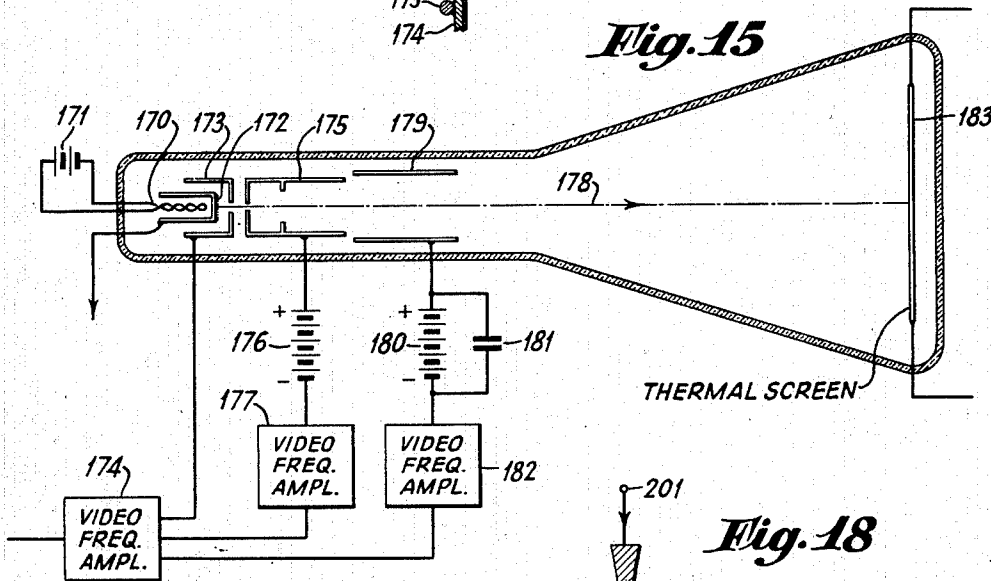


Fig. 16

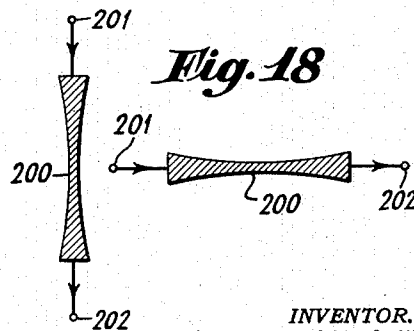
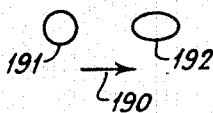


Fig. 18

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Fig. 17

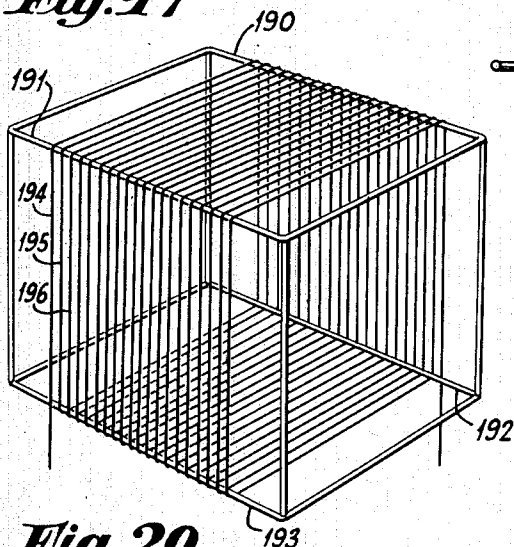


Fig. 19

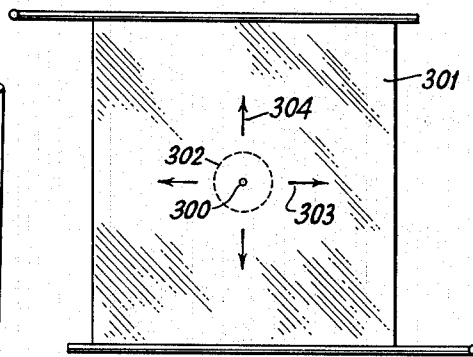


Fig. 20

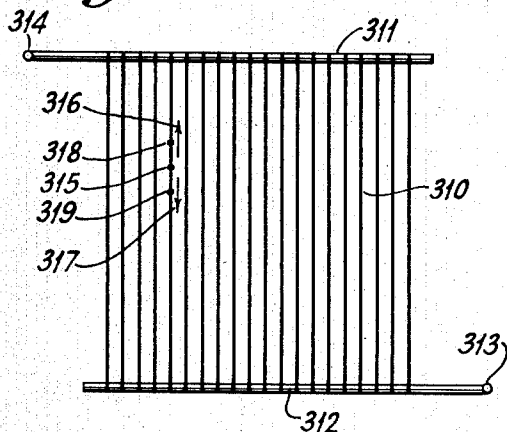


Fig. 21

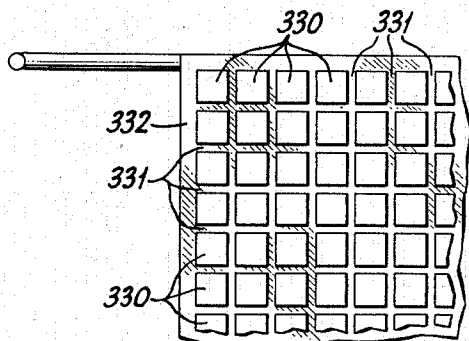
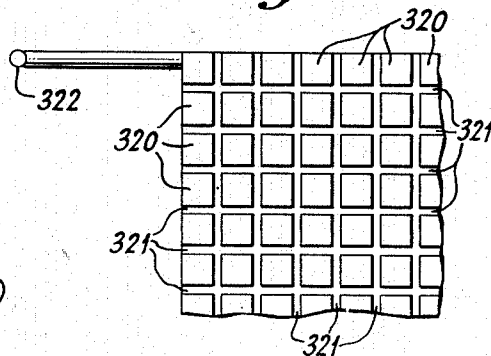


Fig. 22

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UNITED STATES PATENT OFFICE

2,280,946

THERMAL OPTICAL IMAGE REPRODUCING
SYSTEM

Alfred N. Goldsmith, New York, N. Y.

Application November 1, 1939, Serial No. 302,309

9 Claims. (Cl. 250—164)

My invention relates broadly to devices for reproducing optical images, and more particularly to a system and apparatus for reproducing such images which are sufficiently intense in light value as to be projected and magnified to form comparatively large sized images.

Presently known television receivers and reproducers form the reproduced optical image by means of the action of a moving modulated electron beam which impinges on a fluorescing material, thus producing light due to the fluorescent properties of the material. It has been recognized, however, that there are definite limitations attendant the use of such material. The light formed is not sufficiently intense to be projected through a lens system onto a larger area with the formation of an adequately bright image due to the comparative feebleness of the light in the original image, and both the fact that large amounts of light are lost in its transmission through lens systems and to the fact that the amount of light (light flux in lumens) per unit area on the screen upon which the magnified image is cast varies inversely as the square of the ratio of respective linear dimensions between the magnified image and the image reproduced on the end of the tube.

The problem of providing a screen which will reproduce an optical image with a light sufficiently brilliant to be satisfactorily projected to large dimensions has been the subject of experimentation by a number of investigators. Screens have been provided of the so-called "thermal" type, that is, where the light produced is the direct result of the heating of the screen rather than that due to any inherent fluorescing properties, and so-called "thermal" screens or "thermal" images have been utilized for this purpose with varying degrees of success. Accordingly, it is one of the objects of my invention to provide suitable structures for the formation of thermal images due to the energy of impact of a modulated scanning electron beam.

One of the drawbacks to the previously known thermal arrangements has been that a comparatively large temperature change must occur between the normal operating temperature of the screen and the temperature at which a brilliant light is formed. Accordingly, it is another of the objects of my invention to provide suitable means for increasing the thermal sensitivity of such a screen by the use of supplemental heating currents which raise the temperature of the screen to a point where the screen is only feebly visible or just below the temperature at which visible

radiation occurs (that is, at low color temperature).

In carrying out the aforementioned object, namely that of raising the temperature of the screen to a threshold value, it is not only desirable to provide apparatus and means for heat "biasing" of the screen, but the apparatus for accomplishing this object should be as simple and as feasible as possible. Accordingly, it is another of the objects of my invention to provide convenient structures and apparatus for use with moderate threshold currents for initially raising and maintaining the thermal screen at a heat which is very close to the temperature at which visible radiations occur. The visibility of the radiations herein referred to is to be determined in the enlarged projected image.

One of the drawbacks of the use of thermal screen heretofore known has been the fact that at very intense heats, the possibility always exists that the screen may burn out. In the plane-faceted thermal screens heretofore known, this concentration of heat at one or more points tended to puncture the screen or produce spots which are readily visible and annoying to an observer. Accordingly, it is another of the objects of my invention to provide such structures with means for minimizing the danger of burn-out in portions thereof and to minimize the annoying and undesirable effect of a partial burn-out.

It has been brought out hereinbefore that heating of the screen to an initial bias temperature and the maintaining of the screen at this temperature was accomplished by the use of threshold currents flowing in the screen itself. These currents produce a potential drop in the screen and, as is well known in electrical theory where currents flow through such members, equipotential lines resulting from this flow are produced on the conducting surfaces. Accordingly, it is another of the objects of my invention to provide supplementary electrical means whereby such equipotential lines resulting from the threshold current flow or otherwise shall be controllable.

Such thermal image screens must be supported in such fashion within the normal cathode ray reproducing tube that the screen does not sag or bend unduly when it is heated intensely, and naturally this may not be done with rigid supporting means in fixed positions. Accordingly, it is another of the objects of my invention to provide means for the suitable mechanical support of such thermal image producing surfaces or structures whereby the screen not only is ade-

quately supported, but the resultant structure is such that there is the probability of a minimum of injury from shock and allowance for dimensional changes resulting from temperature changes.

Again, I have found that the shape of the scanning spot which is used plays an important part in the accurate reproduction of a thermal image. This spot should under some definite conditions vary from the circular, as is common practice today, to the elliptical in shape. Accordingly, it is another of the objects of my invention to provide means for varying the shape of the scanning spot with reference to the direction of motion of the scanning spot and, in accordance with the requirements, for the best delineation in the thermal image.

I have found that not only should the shape of the scanning spot be varied under definite circumstances, but that the size of the scanning spot also should be varied in accordance with the variation in the modulation of the beam, and it is a further object of my invention to vary the size of the electron scanning spot in accordance with variation in intensity of the electron beam for the purpose of securing optimum delineation in the thermal image.

Since the thermal screen member is of necessity heat-conducting, there is a fair amount of heat conducted away from the particular spot on which the electron beam is impinged on the screen member at any particular instant. There is a tendency of the heat produced thereby to "spread." Accordingly, another of the objects of my invention is to provide an arrangement which will limit or prevent thermal spread of the image radially outward from the screen element which has just been raised to a high temperature by the scanning spot.

In addition, it is also desirable to control the rate of conduction both of the heat and electrical charges from each portion of the image screen and, accordingly, it is another of the objects of my invention to control the rate of conduction of the heat and electric charges away from each portion of the image screen.

Accordingly, among the objects of my invention are:

1. To provide suitable structures for the formation of thermal images due to the impact of a modulated scanning electron beam.
2. To provide suitable means for increasing the thermal sensitivity of such a screen by the use of supplemental heating currents which raise the temperature of the screen to a point where the screen is only feebly visible or just below the temperature at which visible radiation occurs in an enlarged image thereof.
3. To provide convenient structures and apparatus for use with moderate threshold currents for initially raising and maintaining the thermal screen at a heat which is very close to the temperature at which visible radiations occur in an enlarged image thereof.
4. To provide such structures with means for minimizing the danger of burn-out in portions thereof and to minimize the annoying and undesirable effect of a partial burn-out.
5. To provide supplementary electrical means whereby equi-potential lines in the conducting screen resulting from the threshold current flow therein or otherwise shall be controllable.
6. To provide means for the suitable mechanical support of such thermal image producing surfaces or structures whereby the screen not

only is adequately supported, but the resultant structure is such that there is the probability of a minimum of injury from a shock and allowance for thermal expansion.

7. To provide means for varying the shape and size of the scanning spot with reference to the direction of motion of the scanning spot and in accordance with the requirements for the best delineation and most nearly uniform color in the thermal image.

8. To provide means for radiating with high efficiency light from the structure on which the thermal images are formed, by the coating of said structure in the direction of visual utilization or projection with material which are especially efficient selective radiators in the visual range of light frequencies.

9. To provide means for reducing secondary emission from, and space charges near, such structures for the formation of thermal images by coating such structures in the surface impacted by the electron beam with appropriate materials of low secondary emission characteristics.

10. To limit or prevent thermal spread of the image radially outward from the screen element which has been raised to a high temperature by the impingement of the scanning spot thereon.

11. To control the rate of conduction both of heat and electric charges away from each portion of the image screen.

My invention in general comprises providing a thermal screen which consists of individual sections which may or may not be of changing thickness, this depending upon the particular desired operation of the device. These individual sections are adapted to be heated by the action and impact of a modulated cathode ray beam which contacts therewith. The screen itself is raised to an initial bias temperature which is at or near the point where visible radiation occurs. The means for providing the initial bias taken together with the particular structure of the screen comprises an important feature of the invention. Ways and means are provided which will be explained more in detail hereinafter for changing the cross-sectional shape and size of the modulated cathode ray beam, and this also is an important feature of my invention.

The screen member per se may be comprised of individual planar sections or of wires as will be hereinafter illustrated; and particularly in the case of the wire type or thermal screen the cross-sectional area of the wires may be varied as will be explained more fully hereinafter. The wires themselves may be partially coated with a material having desirable secondary emission characteristics, or with a material having efficient selective radiation in the visible range, or both, and this will be explained more in detail hereinafter.

My invention will best be understood by reference to

Figs. 1 through 10 which show embodiments of thermal screen members with means for raising the screens to a bias temperature.

Figs. 11 through 14 show particular thermal screen sections,

Fig. 15 is a system embodying my invention,

Fig. 16 shows a cross-section of the scanning spot during deflection,

Fig. 17 is a form of thermal screen,

Fig. 18 is a cross-section in vertical and horizontal planes of a plate anode,

Fig. 19 is a schematic showing of the radial spread of a thermal spot on a plane screen,

Fig. 20 shows the thermal spread of a spot on the wire type of thermal screen,

Fig. 21 is an arrangement for preventing thermal spread, and

Fig. 22 is an alternate arrangement to Fig. 21.

Referring to Fig. 1, there is shown one type of thermal screen. In this arrangement, a thin wire 1 is wound progressively to and fro around a series of insulating pegs such as 2, 3, 4 and 5. One end of the wire is joined to a terminal such as the terminal member 6, and the other end of the wire to a terminal such as the terminal 7. Connected serially with the wire forming the anode is an inductive member 8, whose purpose is to suppress flow of high frequency currents through the anode. In turn, this inductive member is connected serially to a regulating resistance 9 and a source of energy, which in this case is a battery 10. When the arrangement is used in a cathode ray tube, the anode potential is applied to the wire by a source indicated by the plus sign, and this can be done as desired at any convenient connection point between 1 and 4, or 3 and 5, or the like.

The wires forming the anode are comprised of any suitable refractory material such, for example, as tungsten or other substances or compounds, some of which have been used hitherto in incandescent lamps. The wire may be bare or may be coated on the side thereof which normally is exposed to the observer with selective luminous radiators of high efficiency of radiation in the visible range, such as the rare earth salts, or may be coated on its front, that is, the side adjacent the scanning beam in a cathode ray tube, by substances which reduce secondary electron emission, as for instance colloidal graphite, or may be coated both on the front and back as described.

The wire is stretched and runs in a direction perpendicular to the direction of motion of the scanning spot. In Fig. 1, for instance, the scanning spot moves horizontally across the vertical wires. This angular relationship is important for wire structures in order to prevent irregular effects or patterns or discontinuities which might result if the direction of motion of the scanning spot were parallel to the wires.

The diameter of the wires should be smaller than that of the scanning spot, and the number of wires from left to right in the figure preferably should be at least as great as the number of elementary dot elements horizontally. For example, in a 441 line picture having an aspect ratio of 4 to 3, there should be preferably at least 588 vertical wire sections and, in practice, these should be approximately $\frac{1}{10}$ or $\frac{1}{8}$ of the diameter of the scanning spot. This should leave adequate space between the wires and yet should give the impression of a substantially continuous structure, at illuminated portions of the picture due to the effect of irradiation when viewed by the human eye, that is, the apparent spread of any brightly luminous area.

The illumination of any portion of this structure as hitherto described would depend solely upon the energy in the scanning electron beam. The sensitivity of the arrangement can be enhanced however by the following method: It will be noted that the source of energy 10, the resistance 9, and the wire are in series with each other. By means of the adjustable resistance 9, the current through the wire grid is regulated

until the entire grid is either a faint red in color or even only invisibly thermally radiant, this being preferably judged on the projected enlarged image under normal viewing conditions.

When this is done, the sensitivity is greatly increased because the electron beam need not raise the temperature of any portion of the grid or anode by so great an amount to bring the screen up to a markedly visible illumination.

The anode connection from the positive end of the high potential source indicated by the positive sign may be connected to any intermediate portion of the wire member as well as that indicated in the drawing.

The current which enters the anode from the scanning electron beam must be led off without detriment to the wire continuity or the picture quality. Among the methods of this invention for these purposes is the systematic variation of the diameter of the wire forming the grid in such fashion as to

(a) Reasonably equalize the temperature rise caused by electron beam conduction currents in all portions thereof, and

(b) If desired, to increase the brightness of the picture in its central portions since these are generally the center of interest.

The increase in the diameter of the wire of the grid-like anode will, therefore, be continuous from one end thereof to the other, or it may be continuous from the center of the grid-like anode to each end thereof, or it may be varied otherwise in accordance with the special conditions in any particular arrangement.

Referring to Fig. 2, there is shown an arrangement somewhat similar to that as disclosed in Fig. 1 except that all of the wires 20 of the grid-like anode are connected in parallel between heavy terminals 21 and 22. The primary, or threshold, heating current is provided from the circuit comprising a source of electrical energy which in this instance is a battery 23 or other equivalent heating source, a regulating resistance 24 and an inductive member 25, the latter being provided to act as a high impedance to high frequency currents. Connected across the heavy bar members 21, 22, and preferably across the diagonally opposite edges thereof is a by-pass condenser 26 which acts as a substantial short-circuit path for video frequency currents generated in the grid-like anode by the electron stream of the scanning beam. To equalize applied voltage to each of the parallel wires 20, the heating current is also applied to the diagonally opposite corners of the assembly as illustrated.

Since the heating current in this embodiment as illustrated may be large, it may be preferably generated by either a low voltage high current source or else may be provided from the secondary of a step down transformer.

Referring to Fig. 3, there is shown another more flexible and generally preferable embodiment of the grid-like anode. In this arrangement, there are provided groups of wires forming the grid, the groups being serially connected but the individual wires forming each group being connected in parallel. Wires such as 30, 31 and 32 are connected in parallel at one end of the bar-like member 33 and at the other end thereof to the bar-like member 34. Also connected at one end thereof to the bar-like member 34 are wires such as 35 and 36, the latter being connected at the other end thereof to the bar-like member 37. In turn, the wires of the next group, one of which is illustrated at 38, have one end

thereof connected to the bar-like member 37, and the other end thereof connected to the bar-like member 39. The next group has one end thereof connected to the bar-like member 39 and the other end thereof connected to the member 40, and the final group illustrated has one end thereof connected to the member 40 and the other end thereof connected to the member 41. Thus each group has the wires thereof connected in parallel, and the groups themselves are serially connected. Thus, the threshold current passes through the groups serially by being connected to terminals 42 and 43. The source of threshold current may be that as illustrated in Figs. 1 and 2, or as suggested hereinbefore in the specification. Supplementary terminals such as 44, 45, 46, 47 and 48 are provided to enable connection of the positive anode biasing potential from the source of bias to any desired section of the grid-like anode. The wire direction, diameter, diameter grading if desired, and the like, are similar in general to the arrangements described in connection with Fig. 1.

Referring to Fig. 4, there is shown an example of a previously known thermal screen connected so as to be raised to an initial bias temperature. The screen member 50 may be comprised of a sheet of refractory material such as tungsten or the other materials hereinbefore indicated in this specification, and a sheet is fastened directly between the bar-like conductors 51 and 52. The initial bias temperature may be brought about by the same arrangement as illustrated hereinbefore with respect to Figs. 1 and 2, wherein there is shown a source of electrical energy connected serially with a potentiometer and an attenuating inductance, the series circuit being connected to the terminals 53 and 54. The anode potential may be applied to one of these terminals or to any intermediate part of the screen.

Fig. 5 shows an arrangement which is alternative to that of Fig. 4 and wherein the sheet of refractory material 60 is connected between bar-like members 61 and 62. As in the case of Fig. 4, the potential for raising the screen to a bias heat may be supplied by an arrangement similar to that of Figs. 1 and 2 and may be connected to the terminals 63 and 64. The anode high potential may be applied as in the case of Fig. 4. In this case, however, the current flow through the screen due to the current which raises the screen to an initial temperature is parallel to the direction of motion of the electron scanning spot. This is in contradistinction to the arrangement of Fig. 4 wherein the current which flows to the screen to heat it to an initial bias temperature flows in a direction which is perpendicular to the motion of the scanning spot.

Fig. 6 represents a still further embodiment of the sheet type of screen. In this instance, the screen is illustrated as comprised of three individual sheet-like members 70, 71 and 72. These individual sheets may be considered as being analogous to the individual groups of wire members disclosed in Fig. 3. The three sheet members here illustrated are connected serially, the sheet 70 being connected to the bar-like members 73 and 74 at the extremities thereof; the sheet 71 being connected to the bar-like members 74 and 75; and the sheet 72 being connected to the bar-like members 75 and 76. The current which provides the initial heat bias may be joined to the terminals 77 and 78 and the high anode potential may be applied to the members at one of these terminals or at any desired intermediate

point. The arrangement as illustrated here with narrow gaps between the sheet members permits the use of smaller threshold heating current.

The individual sheets here illustrated as 70, 71 and 72 may be made as narrow in the direction of motion of the electron scanning spot as may be desired, until they finally approximate the arrangement shown in Figs. 2 and 3 wherein wires are used. In other words, the individual plate or sheet sections may be shrunk in width to the diameter of the wires in the grid-like anodes previously described. The arrangement as shown in this figure is also operative if turned at right angles to its present position with reference to the direction of motion of the scanning spot. This, however, is not the preferred embodiment since it places the slots, such as the slot 79, parallel to the direction of motion of the scanning spot.

Referring to Fig. 7, there is shown a wire grid-like anode somewhat similar to that disclosed in Fig. 2 and, in general, similarly used. In this case, wires such as 80, 81 are connected between bar-like conducting members 82 and 83 in the same manner as in Fig. 2. However, supplementary wires such as 84, 85 and the like, are placed in close contact with, and may in some instances be welded to, the vertical wires such as 80 and 81. This ensures substantially equal potentials on all points of the wires in a given horizontal line. The horizontal wire such as 84 and 85 may be left disconnected or alternately they may be connected with suitable resistances such as resistances 86, 87 and 88. This series of resistances may alternatively be connected either to the ground or to any other potential source including the high potential anode supply. In this way, anode power can be supplied from the lengths of the grid wires, for example, by connection to the central point of the resistance series 86, 87, 88, and it is also possible to control in this manner the potentials at all points of the system.

Referring to Fig. 8, there is shown a mode of supporting a grid-like anode which has been formed similarly to that shown in Fig. 2, the grid-like anode being comprised of a series of individual parallel wires connected to two bar-like electrode members. The individual wires in this case are illustrated such as 90 and 91, and are connected to the bar-like conducting members 92 and 93, the latter members containing terminals 94 and 95 to which may be connected the current for supplying the initial heat bias. The members 92 and 93 in this instance are spring supported by spring members 96, 97, 98 and 99, the springs being attached at the ends thereof remote from the attachment to the anode to fixed surfaces such as 100 and 101. These fixed surfaces may be either insulating material or conducting material suitably insulated from other parts of the system. The springs should in general be under tension.

Referring to Fig. 9, there is shown a similar spring supporting method for anodes of the grid-like type such as disclosed in Fig. 3. In this arrangement individual wires such as wires 110 and 111 are formed into groups, and these groups are serially connected to the bar-like members 112, 113, 114, 115, 116 and 117. The current which produces the initial heating bias may be impressed onto the anode by terminals such as terminals 118 and 119. The high voltage anode potential may be applied at one of

these terminals or any desired intermediate section of the anode. In this instance, the individual bar members are illustrated as being held in contact with supporting surfaces such as 120 and 121 by spring members such as the member 122 in the same manner as hereinbefore explained with respect to Fig. 8. Two methods of spring support are indicated in this drawing. One of the methods is that illustrated in holding the bars 112 and 113 and wherein the bars are supported only at the center thereof. The other type is illustrated in holding the bars 116 and 117 and wherein these bars are each supported at two points at or near their ends. More springs can be used if desired for equalization of end tensions.

Referring to Fig. 10, there is shown a means of supporting an anode member of the same general structure as that described in Fig. 1 wherein the grid-like anode is formed of a single wire wound to and fro around a set of peg-like members. In this case, the wire 130 is wound about peg-like members such as 131, 132, and 133; and the pegs themselves are fastened into insulating supports 134 and 135. The initial heat bias current may be supplied at the terminals 136 and 137. The insulating members 134 and 135 are mechanically connected to support members 138 and 139 by spring members such as spring 140.

Referring to Fig. 11, there is shown a cross-section of several wires arranged adjacent each other and the side on which the wires are scanned is indicated by the arrow. These wires, four of which are illustrated, such as 150, 151, 152 and 153 are coated on the side opposite the scanning beam, that is to say, the side thereof remote from the action of the scanning beam by a material giving a maximum efficient radiation in the visible spectrum when heated. One such coating is illustrated as 154. Such material can similarly be applied to the back of a thermal image producing plate such as illustrated in Figs. 4 through 6, the back being the section remote from the action of the scanning electron beam.

Referring to Fig. 12, there is shown a single wire element 160 wherein one side thereof, which in this case is the side remote from that on which the electron scanning beam impinges, is coated such as illustrated at 161 with a material which radiates selectively and efficiently in the visible spectrum when heated. Such substances may, for instance, be the rare earths and their salts or similar refractory materials such as are used in Welsbach mantles and Nernst glowers. Any other materials having similar properties may be used for this purpose. When applied, these materials face either the observer or the optical system which will enlarge and project the thermal image.

Referring to Fig. 13, there is shown an arrangement wherein four wires of a grid-like anode are illustrated as wires 170, 171, 172 and 173. These wires rest against a thin electrically conducting or non-conducting plate 174, the back of which is coated with a selective radiator 175 and the front of which may be coated with a material having a minimum secondary electron emission property such, for instance, as colloidal graphite. Hence, the side of the anode exposed to the action of the scanning beam releases a minimum number of secondary electrons.

Referring to Fig. 14, there is shown a somewhat enlarged cross-section of one portion of Fig. 13 and this illustrates also a welding or a soldering between a single wire member 180 and

the plate 181, the welding or soldering being illustrated at 182, and the coating of the substance having a maximum radiation within the visible spectrum being illustrated at 183.

Referring to Fig. 15, there is shown a system embodying my invention. This is an enlarged drawing in the plane of the electron gun of a kinescope (not shown). A heater element 170 is connected to an A. C. or a D. C. source of power, which in this case is illustrated as being the direct current source of power 171. Positioned adjacent the heater element is an emissive surface 172, and the electrons emitted therefrom pass through the aperture in a control grid 173, the latter being connected to the output of the video frequency amplifier 174, the video frequency amplifier being connected in the television receiver. The beam then passes through the aperture in the first anode 175, the latter being energized by a source of power which, in this case, is illustrated as direct current source 176. The element 176 in turn is connected to a video frequency amplifier 177, whose input is joined to the output of video frequency amplifier 174 so that the potential of the first anode swings around a median value determined by the potential value of the direct current source 176, the swing being either in phase with the potential changes of the grid 173 or in opposite phase thereto or in other phase relation thereto as may be desired. The potential source 176 may have a condenser (not shown) shunted across its terminals to permit the ready passage of video frequency charging currents. The scanning beam in the direction as indicated by the arrow identified as 178 passes through the aperture in the focussing second anode 179 which is also at positive potential, the potential being supplied by the source of direct current power 180. A condenser 181 is shunted across the terminals of the source of direct current 180, and the negative side of the source is connected to the output of a video frequency amplifier 182 having its input connected to the output of video frequency 174. In this way, the second anode 179 may also be swung in potential at video frequency either in the same or opposite or other phase relationship to the swings of the grid 173. The beam then passes through appropriate deflecting fields which are not illustrated here, but which are well known in the prior art, and impinges onto the thermal screen 183.

The object of the arrangement shown in this figure is as follows: In the bright parts of the picture, the control grid of the electron gun permits maximum beam current to flow through the gun. At the same time, the first anode permits a maximum size of beam, and the second anode focusses it only to such an extent as to produce a scanning spot of correct size on the grid-like plate or sheet-like plate on which the thermal images are formed. If, however, a half tone or reduced brightness part of the picture is being scanned, the grid 173 cuts down the beam current, the first anode may reduce the size of the spot somewhat and the second anode will focus the spot to a smaller size. The result is that a smaller area on the thermal image producing elements will be rendered incandescent and, accordingly, while the light emitted therefrom will be reduced as compared to that corresponding to a high light, its color temperature will be almost the same. The method of delineation then comprises variable dot areas of more nearly constant color temperature rather than

approximately constant dot areas of variable color temperature. By "dot" is meant the hypothetical dot element forming the television picture. The most desirable adjustment of the video frequency potential variations of the elements shown in Fig. 15 may be determined theoretically but is probably accomplished more conveniently by experimental trial.

It will be seen therefore that this arrangement produces a picture or thermal image which has more nearly the same color in the high lights and half tones. This requires that the range of temperature with which the image is formed shall be reduced since there is a change in the color of a self-luminous body as its temperature is raised. The desired result of a more nearly constant color temperature in all delineating parts of the thermal image is accomplished by changing the size of the scanning spot in accordance with the video frequency potentials which indicate the brightness of each point of the picture. It will be understood that the electron gun structure and the circuits of Figure 15 are purely illustrative, and that their equivalents may be similarly used without falling outside the scope of this invention.

Another element of this invention is the suitable shaping of the scanning spot for the purpose of producing such thermal images. The usual scanning spot is approximately circular since it travels at a high rate of speed, and accordingly the amount of energy which can be transferred therefrom to a given area of the anode over which it passes is limited. It is possible to expand the scanning spot in a direction parallel to its motion, that is, along the scanning line. Such an idea is shown in Fig. 16 wherein the arrow 190 indicates the direction of motion of the scanning spot. Instead of the scanning spot being circular as shown by 191, it may be made approximately elliptical as shown in 192, the major axis of the ellipse being parallel to the direction of motion of the spot. To secure this properly oriented elliptical scanning spot, the orifices in electrodes 173 and 175 in Fig. 15 are suitably shaped thus to control the desired beam cross-section. It will not be necessary, in general, also to flatten the cylindrical electrodes 175 and 179. While it might seem that this elliptical scanning spot would reduce definition along the scanning line, yet the concentration of electrons toward the center of the scanning spot together with the thermal inertia of the anode wires or plate render such an effect negligible if the eccentricity of the ellipse is not too great and its time of passage over any element of the thermal screen is sufficiently brief.

Another object of the invention is a convenient method of manufacturing such grid-like anodes as are shown for example in Figs. 1 through 3. The particular arrangement selected for illustration is one similar to that of Fig. 3, but other arrangements are equally readily produced by obvious modification. Referring to Fig. 17, such an arrangement is shown.

A framework of heavy wires or similar supporting elements such as illustrated as 190, 191, 192 and 193 is formed as a rectangular parallelepipedon. The wires forming the grid-like anode are wound continuously between one end and the other end of the parallelepipedon. Such wires are indicated for instance as 194, 195, 196. The supports 190 through 193 are then supported and welded by usual methods at the edges thereof. To form the gaps between adjacent support

elements, which must be placed according to the arrangement as shown in Fig. 3, gang cutters are used to cut through the long sides of the support elements 190, 191, 192 and 193 at definitely desired points. The separated structure is then ready for use with minimum further handling. Internal supporting members may be used to hold the grids taut until they are assembled on their spring supports as shown in Fig. 9.

Referring to Fig. 18, there is shown a typical cross-section in vertical and horizontal planes of a plate anode for thermal images. Such plate anodes have been illustrated hereinbefore in Figs. 4, 5 and 6. It will be noted that the plate 200 is thinnest at the center thereof and thicker at the edges. The initial heat biasing current may be applied to the plate at the terminals 201 and 202 thereof. This construction tends to brighten the center of the image.

Referring to Fig. 19, there is shown an illustration of the manner in which the thermal spot tends to spread when striking the plane type of thermal screen. The spot impinges at the point 300 on the thin foil type of metallic screen 301, and the heat therefrom tends to be conducting equally in all directions from the point of impingement, if we assume that the foil screen is equally conducting at all sections thereof. Such a spread is illustrated by the dotted circle 302, and it will be noted therefore that the spread tends to take place in both coordinates 303 and 304 of the reproduced image.

Referring to Fig. 20, the screen illustrated in this instance comprises such an arrangement as illustrated in Fig. 2 and wherein wire members 310 are stretched between heavy conducting members 311 and 312, the initial heat bias from the screen being supplied by current impressed on the terminals 313 and 314. The spot impinges by way of illustration at the point 315, and tends to spread in the direction of the arrows 316 and 317 as illustrated by the dots 318 and 319.

Referring to Fig. 21, there is shown one form of apparatus for minimizing the radial outward radiation or prevention of thermal spread of the image. The general method of and apparatus for accomplishing the results is somewhat as follows: A carrier or support of an insulating material, such as glass or some opaque material such as lavite, alsimag, or similar heat-resistant insulators is used as the base for the actual target screen. This screen consists essentially of a checkerboard-like screen of rectangular or square minute plates of metal preferably of dimensions less than the cross-sectional dimension of the scanning spot, these minute plates being arranged in regular rows and columns. They may be produced by depositing a heavy layer of metal on the insulating surface, and then by scribing or engraving the vertical and horizontal divisions between the unit platelets, a suitable engraving machine being used. Alternatively, the division may be etched by coating the metal sheet with an acid resistant material or ink of the proper pattern, and etching the resulting sheet, after which the wax, ink, or other resistant material may be removed.

In the arrangement shown in Fig. 21, the backing plate of insulating material is not shown but there are illustrated the metallic squares or rectangular sections such as 320 which are separated by narrow grooves 321, the grooves forming the metallic deposit into a set of individual rectangular or square metallic elements. It will be appreciated that these elements need not be

entirely separated from each other since by etching or cutting the original metallic deposit to a depth slightly less than its thickness, the ordinary spread of the heat will be prevented since a great deal of the conducting surface between elemental sections has been cut away. This also offers the advantage that the screen may be raised to an initial bias temperature by impressing current onto the terminals 322 and 323 in the same manner as illustrated hereinbefore with respect to Fig. 4.

Alternatively, the surface of the insulating material may be covered by a great multiplicity of small approximately circular and irregularly spaced platelets, these being produced by a fine spray of melted metal against the sheet of insulating material. The individual approximately circular platelets will then be in an irregular arrangement which nevertheless will substantially cover the surface of the insulating backing and will leave spaces between the unit platelets.

In the arrangement according to Fig. 22, the individual platelets are shown as approximately rectangular members 330 spaced apart by grooves 331. These individual metallic squares are deposited on a heat resistant and insulating backing 332.

A further alternative method of producing the unit platelets on the insulating support is to cover the insulating surface with a fine layer of some metal, such as silver, and then, by the application of heat, to form a mosaic arrangement on the insulating surface, after which the mosaic arrangement in question can be plated heavily with any other desired metal as, for example, platinum. The metal used for plating should be strongly heat resistant.

Having thus formed a sheet of insulating material, which is preferably transparent, and on which are distributed regularly or irregularly a great number of heat resistant minute unit platelets of metal, it is evident that the spread of heat laterally over the surface which would result in apparent increase in the dimensions of a point of light on the surface of the screen produced by electron impact, will be reduced substantially as compared to convection and radiation losses. Accordingly, apparent image spread should be minimized in such a structure.

In order to control the degree of lateral, terminal conductivity between the unit platelets, a further thin coating of a heat conducting and preferably heat resistant metal should either be plated or sputtered by conventional processes over the surface of the mosaic. The thicker such coating may be, the greater the lateral thermal conductivity, but, on the other hand, the greater the tendency toward lateral spread of the thermal image elements.

It will be appreciated that departures may be made from the particular apparatus or portions thereof disclosed hereinbefore which will still fall fairly within the spirit and scope of my invention. Accordingly, I do not limit myself to the particular arrangement and every detail thereof but feel entitled to that which may fall fairly within the spirit and scope of the invention as set forth in the hereinafter appended claims.

What I claim is:

1. In a cathode ray tube, a current conducting thermally responsive target element adapted to incandesce under the influence of electron bombardment, means to develop an electron stream and to direct the stream upon the target, means to direct the stream to traverse the target linearly

according to a predetermined scanning path throughout a definite working area of the target, and means for passing a current through the target along a path at all times substantially normal to the selected predetermined scanning path, said current being impressed onto said target through only one pair of diagonally opposite terminals onto a pair of low resistance conductors lying along substantially opposite segments of the boundary of the target.

2. In a cathode ray tube, a current conducting thermally responsive target element comprising at least one thin sheet of conductive material adapted to incandesce under the action of electron bombardment, means to develop an electron stream and to direct the stream upon the target, means to direct the stream to traverse the target linearly according to a predetermined scanning path throughout a definite working area of the target, and means for passing a current through the target along a path at all times substantially normal to the selected predetermined scanning path, said current being impressed onto said target through only one pair of diagonally opposite terminals onto a pair of low resistance conductors lying along substantially opposite segments of the boundary of the target.

3. A thermal screen comprising a plurality of individual substantially planar thin sheet conducting members adapted to incandesce under the action of electron bombardment perpendicular to the width of said members, conducting means connecting said sheet members serially, and means for passing a current through said sheet members whereby the temperature of said screen is raised to an initial predeterminable value.

4. Apparatus in accordance with claim 2 wherein the thermally responsive target element comprises a plurality of individual thin sheet conducting members which are connected serially and wherein the current passed through said members is impressed on said members so that the current flow is in a direction substantially normal to the selected predetermined scanning path.

5. A thermal screen comprising a plurality of serially connected individual wire sections adapted to incandesce substantially along the entire length thereof under the action of electron bombardment, said wires being coated on that portion of their periphery exposed to electron bombardment with a material having a high radiation in the visible spectrum when heated.

6. A thermal image screen comprising at least one conducting element adapted to incandesce under the action of electron bombardment, each such element having a cross-section of different dimensions in various parts thereof which are subject to electron bombardment and which contribute to thermal image production.

7. In a cathode ray tube, means to develop an electron stream, a thermally responsive target comprising a plurality of serially connected wire sections, each of said wire sections comprising a plurality of individual wire members connected substantially in parallel, means to direct said electron stream upon the target, means to direct the stream to traverse the target according to a predetermined scanning path, each wire of such screen being positioned in a direction substantially normal to the scanning path and a plurality of individual conducting elements connected to said wires between the extremities thereof and positioned substantially normally thereto in the plane of the said wires and lying within the area

subjected to electron bombardment, and means for passing a current through all of said wires to raise the temperature thereof to an initial value.

8. In a cathode ray tube, means to develop an electron stream, a thermally responsive target comprising a plurality of wire sections, means to direct said electron stream upon the target, means to direct the stream to traverse the target according to a predetermined scanning path, each wire in said screen being positioned in a direction substantially normal to the scanning path and a plate member positioned so as to rest against said wire members, said plate member having one side thereof at least partially coated with a material having a high radiation in the visible spectrum when heated. 15

9. In a cathode ray tube, means to develop an electron stream, a thermally responsive target comprising a plurality of wire sections, means to direct said electron stream upon the target means to direct the stream to traverse the target according to a predetermined scanning path, each wire in said screen being positioned in a direction substantially normal to the scanning path and a plate member positioned so as to rest against said wire members, said plate member having one side thereof at least partially coated with a material having a low secondary emission property. 5 10

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