April 11, 1939. P. T. FARNSWORTH 2,153,918

DISSECTOR TUBE

Filed Dec. 31, 1935

Fig. 1.

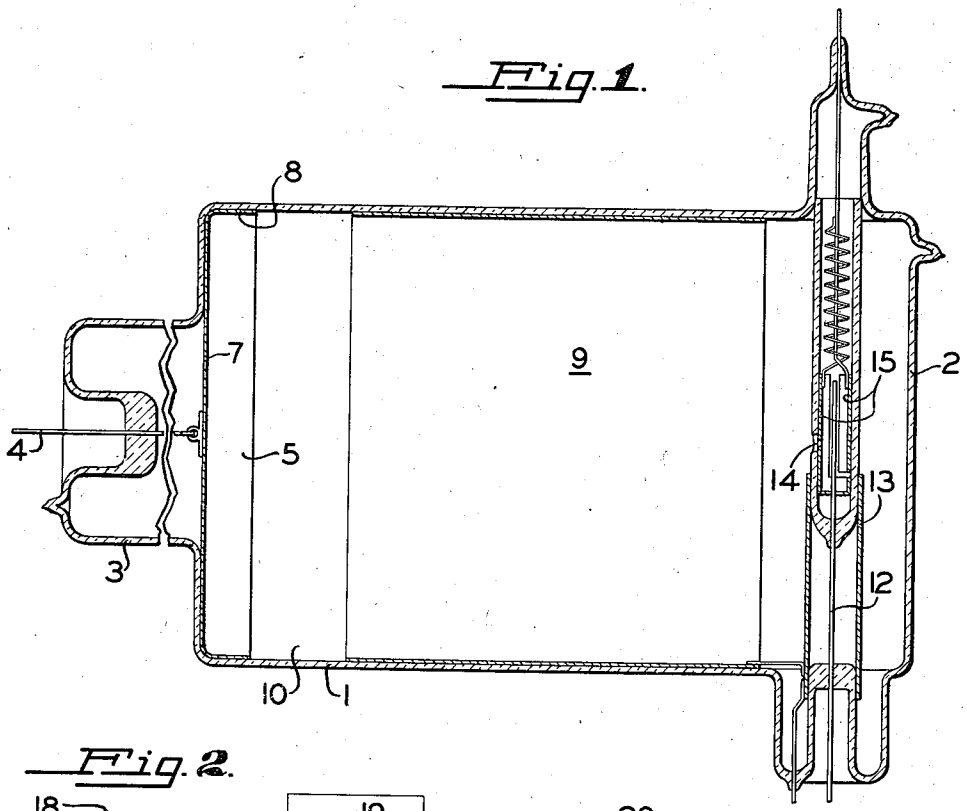


Fig. 2.

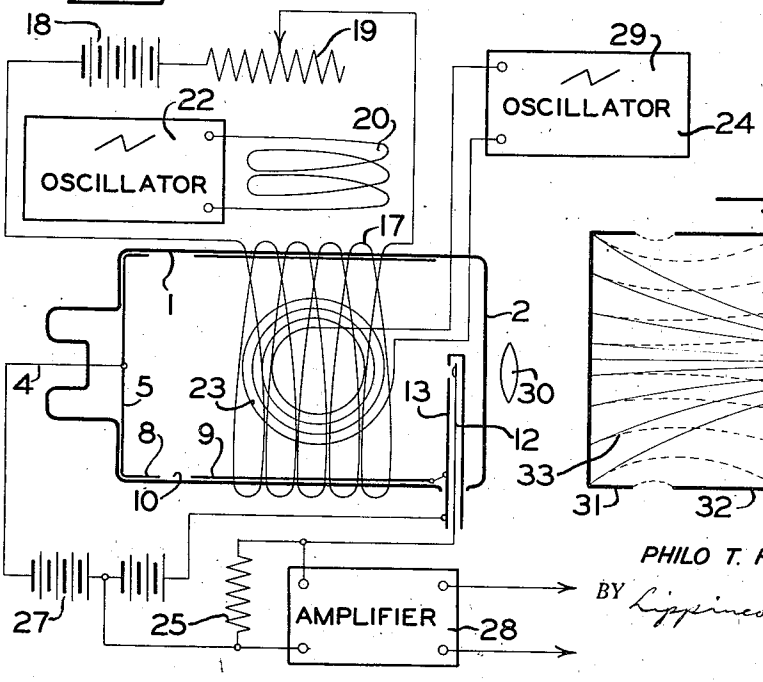
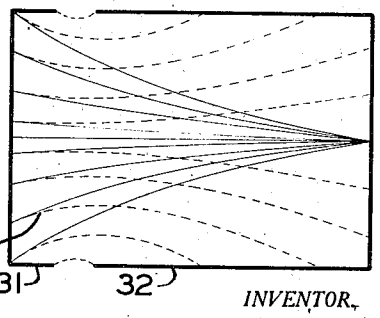


Fig. 3.



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UNITED STATES PATENT OFFICE

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DISSECTOR TUBE

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Application December 31, 1935, Serial No. 56,976

4 Claims. (Cl. 178—7.2)

This application relates to dissector tubes for initiating television signals, and is a continuation in part of my co-pending application entitled "Means and method of interrupting electron multiplication", Serial No. 10,604, filed March 12, 1935.

The primary object of the instant invention is to provide a dissector of the type wherein an electrical image of the field of view to be transmitted is deflected over a scanning aperture, or other collector of electrons having an elementary area as compared with the area of the cathode. The dissector of this particular invention differs from most devices in its class in that the electrical image is undistorted and in focus only immediately adjacent to the electron collector, and that the other portions thereof may be so distorted as practically to lose their image characteristics.

The primary object of the invention is to provide a device wherein the portion of the image undergoing dissection at any instant is sharply in focus, regardless of the degree of deflection of the beam of electrons as a whole. Secondary objects are: To provide a means of dissection wherein the power required for focusing and deflecting the electron beam are greatly reduced; to provide a dissector tube wherein the optical window through which the optical image of the field of view is projected becomes, in effect, a portion of the anode without being made conducting; and to provide a system for the analysis or dissection of a television image wherein the required electric and magnetic field may be established with a sufficient degree of accuracy to provide sharp detail in the resultant picture without requiring structures of excessive bulk or additional complex corrective circuits.

My invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing my novel method. It is therefore to be understood that my method is applicable to other apparatus, and that I do not limit myself, in any way, to the apparatus of the present application, as I may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

Referring to the drawing:

Figure 1 is a longitudinal section through a dissector tube as used in accordance with this invention.

Figure 2 is a schematic diagram of the associated circuits, reduced to lowest terms.

Figure 3 is a line diagram showing the general conformation of the electrostatic field produced in the dissector tube, and the resultant electron paths produced in the absence of the magnetic field.

In television scanning by means of the dissector tube one of the major problems is to maintain accurate focus of the electron image at the scanning aperture in spite of the varying strength of the resultant field produced by the focusing and deflecting coils. Where the image is stationary it is possible to produce a plane focus having an accuracy and resolution comparable to a first class optical image. In producing such a focus magnetically the field is adjusted so that each electron, in its path from the cathode to the anode, accomplishes an integral number of turns along a helical path and returns to tangency with the line of force through its origin in the plane of the aperture. The distance from the source of the electron to its focal surface is directly proportional to the mean velocity of the electron along its path and inversely proportional to the strength of the resultant magnetic field. In general it is advisable to locate the collector or scanning aperture axially of the undeflected beam. If focus is secured in the undeflected condition, the path traversed by the electrons under the condition of maximum deflection, i. e., from the periphery of the cathode to the scanning aperture, is longer than the focal distance in the undeflected condition, and the electrons will therefore have passed through focus and be diverging when the peripheral portions of the image are being scanned. Furthermore, the deflected electrons are passing through a field whose strength is the resultant of the deflecting field and the focusing field, and hence is stronger than either field alone, with the result that the focus is even closer to the cathode than it would be if only the additional length of path were to be considered, thus resulting in even greater divergence of the electron stream at the scanning point.

Several methods of correcting the aberrations thus produced have been suggested, e. g., injecting an alternating component into the focusing field, as suggested in my copending application, Serial No. 550,653. Another compensating method is to form the cathode as a spherical surface, with its center at the scanning aperture, so that all of the paths are of the same length, but this gives only a partial correction which neglects the difference in strength of the focusing field when compounded with the deflecting field.

The method employed in the present invention

has two aspects, both of which involve passing the electron stream through an electrostatic field of non-uniform gradient, and both of which contribute to the final result. The photoelectric cathode is a unipotential surface, and the electrons collected to form the picture current all arrive at the same point. It is obvious, therefore, that the final velocity of all of the arriving electrons must be the same, since each has fallen through the same potential. By making the field stronger adjacent the edges of the cathode than it is at the center, however, the initial acceleration of the peripheral electrons may be increased, and hence, although their final velocity is the same, their mean velocity is greater than for the central electrons, and their focal point is therefore farther along their line of flight, even under the action of the combined deflecting and focusing field.

Considering the other aspect of the invention, the electrostatic field is so devised as to form a type of electrostatic lens which tends to concentrate the entire emission from the cathode in the immediate locality of their point of collection. The tendency of the magnetic field is to spread out the concentrated beam to form an electrical image, but the particular electrons which are being collected at any instant will, as a result of the concentrating action of the field, be traveling along substantially the same paths which they would take were the deflecting field not present. These natural paths of the electrons from all other points will cut, more or less sharply, across the electro-magnetic field, and hence will be acted upon thereby. The function of the magnetic field may therefore be considered as being not so much to deflect desired electrons toward the scanning aperture as to deflect the undesired electrons away therefrom. The electrons collected are therefore almost unaffected by the deflecting field. With all of the electrons originally directed toward the aperture, it is obvious that any deflection thereof will prevent them from reaching it. Closely adjacent the point of collection there will be a small area which has the characteristics of a true electrical image, but it is extremely probable that the remainder of the electrons in the stream are so deflected and confused as to lose practically all semblance to a true image.

In actual practice neither of these effects is carried to its extreme theoretical limit, and there is a certain amount of evidence that at the limits they are mutually exclusive. A compromise is therefore employed. Using the first effect alone, extremely accurate gradation of the static and magnetic fields would be necessary in order to get complete compensation. Using the second effect alone a condition might, perhaps, be achieved at which any value of focusing field whatsoever would be sufficient to divert the unwanted electrons. What is actually arrived at is an effective increase in the depth of focus so that the focusing field be not adjusted exactly in order to give a high degree of definition, and, at the same time, an increase in the mean velocity of the peripheral electrons so as to bring them within the latitude of this increased depth of focus. As a corollary advantage of this adjustment both the focusing and the deflecting field may be made much weaker than is required where magnetic focusing alone is used, with a resultant saving of up to fifty per cent of deflecting current and seventy five per cent of deflecting power, a corresponding saving in equipment cost and with an increase in overall definition.

Considering the invention in detail, the dissector tube, which is the heart of the apparatus, comprises a cylindrical evacuated envelope 1, provided at one end with a window 2 through which the optical image of the field of view may be projected, and at the other end with a reentrant stem 3 through which is brought a lead 4 connecting to the cathode 5. The active surface 7 of the cathode is, as nearly as possible, optically plane, and it is surrounded by a cylindrical flange 8 so that the entire cathode forms a shallow cup or dish. I prefer to form the entire cathode of silver, and to oxidize and deposit caesium on the surface 7 in the well known manner to form a photoelectric surface which is as uniform and sensitive as it is possible to construct.

Starting at some distance from the rim of the cathode is a conductive film 9 formed on the interior of the envelope wall, and extending to a point closely adjacent to the window 2. In practice this coating is extremely thin, and its thickness is grossly exaggerated in the figure merely in order to show it at all. The preferred method of forming the film is to evaporate some metal, such as nickel, within the exhausted tube, protecting the window 2 and the gap 10 between the cathode and the film by means of shields temporarily inserted in place before the final construction of the tube. This results in an additional film beneath the metal of the cathode. No attempt has been made actually to show the film in this portion of the tube, since it coacts with the cathode itself in establishing the electrostatic field and its production as a separate film is partly for the sake of convenience, and partly in order to effect a saving in silver, for with the surface film the flange 8 on the cathode need not be so long as would otherwise be required.

The dimensions of the various parts of the electrical system formed by the cathode 5, a film anode 9, and the space between are all interdependent, and the mathematics required to derive their optimum relationship is excessively involved. As an index of the proper conditions however it may be stated that in a practical tube 4½ inches in cathode diameter, the entire distance between cathode and window is 7½ inches, the cathode flange is ½ inch deep, and the spacing between the rim of the cathode and the film is 1 inch. As will be shown later, the distance to which the anode extends toward the window is not very important, since the window itself assumes a positive potential and becomes, effectively, a part of the anode structure.

The collector of the electrons which are to form the picture current is placed as close to the window 2 as is structurally feasible. This collector may take a number of forms, the simplest being that shown in the schematic diagram, wherein the collector 12 is surrounded by a shield 13, the latter at anode potential, and supplied with an aperture 14 which defines the elementary area, or the cross-section of the electron stream which reaches the collector. In Figure 1 a more elaborate structure is shown involving the use of an electron multiplier or multipactor for proportionally increasing the number of electrons reaching the external circuit. This structure is described and claimed in my copending application, Serial No. 10,604 above-referred to. The action of this device is not germane to the pres-

ent invention, and it should therefore suffice to state that the central electrode or anode 12, the shield 13 and aperture 14 exercise the same functions as in the more simple structure. The two semicylindrical plates 15 are operated at a mean potential corresponding substantially to that of the shield 13, and hence effectively perform the same function, i. e., they are not at materially different potential from the surrounding anode structure.

In the simplified circuit shown in Figure 2 there is shown a focusing coil 17, which is a solenoid surrounding the entire dissector and supplied with a current from a source 18 regulated by a rheostat 19. The tube is encompassed by the necessary deflecting coils, as shown in detail in my former application, Ser. No. 321,805, one pair of coils being represented in the diagram by a single coil 20 supplied by a sawtooth wave low frequency oscillator 22. The lateral deflection is achieved by a similarly disposed pair of coils, with axes at right angles to the coil 20, which are also represented in the diagram by a single coil 23 supplied by a high frequency sawtooth wave oscillator 24.

The collector electrode 12 connects to an output resistor 25 and through a potential source 27 to the cathode 5. The shield 13 is operated at slightly different potential from the collector, and connects to the anode cylinder 9. An output amplifier 28 connects across the output resistor and supplies whatever transmission medium may be used with the device.

In operation an image of the field of view to be transmitted is focused by the lens 30 upon the sensitive surface 7 of the cathode 5. These electrons are attracted toward the anode by the potential applied thereto, which may vary within wide limits but is conveniently of the order of 600 volts. Except that the values of the currents used in the coil system are less there is but one difference, from the operator's standpoint, between the present device and that disclosed, for instance, in my former application, Serial No. 321,805. This difference lies in the positioning of the deflecting coils with respect to the deflection produced by them when the image is in focus. It is well known that where no focusing field is used, the axes of the deflecting coils to produce, say, a vertical deflection, must be horizontal. With a uniform focusing field, and without the use of electrostatic compensation as described in the present application, the axes of the deflecting coils coincide with the direction of the deflection produced thereby, i. e., to produce a vertical deflection the axes of the coils must be vertical. With the setup as here described the focusing coil may be made somewhat shorter than is necessary to produce a completely uniform field, and the axes of the deflecting coils will be made somewhat oblique. In practice, for a vertical deflection, the deflecting coil axis is somewhat nearer the vertical than the horizontal. The coils for producing the horizontal deflection are mounted normally to the vertical deflecting coils; their displacement from the horizontal is similar to the displacement of the vertical deflection coils from the vertical. The exact adjustment is readily found by experiment.

Before considering the action of the electrostatic field, it must be pointed out that the entire window end of the tube is, when the tube is in actual operation, at anode potential. This is brought about by secondary emission from the insulating surface of the envelope. When the beam of electrons is deflected, certain of the peripheral electrons strike the walls of the tube, closely adjacent the anode film, with sufficient velocity to knock out secondary electrons. Electrons from this portion of the wall are collected by the anode, thus placing a more positive charge upon the walls and increasing the velocity of the striking electrons and consequently progressively increasing the number of secondaries emitted up to the point where the walls reach the anode potential. When this condition is established the emitted electrons are re-attracted to the walls and a condition of equilibrium is established. It is not certain exactly what starts the process. It may be some leakage of the positive charge from the film along the glass walls, as it seems reasonable that such leakage should occur.

Whatever the mechanism may be, however, the charge spreads progressively until the entire window has assumed the maximum positive potential and, so far as the field established thereby is concerned, the anode structure assumes the form of a deep cylindrical cup with a flat bottom. The charging of the window takes place almost instantaneously after the device is put into operation, and the charging process is greatly facilitated by intimate contact between the anode and the wall of the envelope. It is for this reason that it is preferred to deposit the anode as a film upon the glass, although it should be obvious that there is no structural reason why it could not be made as a separately inserted metal cylinder.

The action of the electrostatic field produced by the charged surfaces of the anode and the cathode are illustrated in Figure 3. The heavy line 31 indicates the shape of the median section of the negatively charged cathode surface, while the heavy line 32 shows the shape of the opposing surface that is positively charged. For simplicity the collector is omitted, but it is to be noted that this element is located deep within the anode cup, where the shielding action of the walls reduces materially the potential gradient, so that its effect may, for the sake of simplicity, be neglected for the moment.

The dotted lines 33 indicate approximately the direction of the lines of force of the field between the two surfaces. Equipotential planes are not shown, since they would unnecessarily confuse the diagram, but it can readily be seen from the shape of the electrodes that the field will be strong adjacent the periphery of the cathode and relatively weaker at its center, and it will be recognized that a strong field corresponds to a high potential gradient, whereas the weaker field corresponds to a low one, hence the rate at which the peripheral electrons approach their final velocity will be greater than that at which the central electrons reach this same velocity.

The field adjacent the cathode is convergent, but as it approaches the anode it starts to diverge. The force acting upon the electrons at any moment is in the direction of the lines of force. The electrons as they start along their paths tend to follow the lines of force, but the velocities which they acquire prevent their doing so. By the time they have entered the divergent portion of the field they are traveling with approximately 70 per cent of their final velocity, following the paths indicated by the converging lines 33, tending to concentrate at a point closely adjacent the collecting aperture.

As has been stated, the effect of the collector upon the field is relatively unimportant, but such

effect as it does have is to decrease the divergence of the field. It will be recognized that the mutual repulsion of the electrons in the stream would necessarily prevent point concentration, but practice has shown that the concentration which can be achieved is excellent, the beam of electrons which started out with the characteristics of an image over four inches in diameter being brought down to a spot one-half inch or less in size. Where only a small point on the periphery of the cathode is illuminated, so that the repulsive effect of the other electrons is not present, the approximation to the aperture may be considerably closer.

When a stream of electrons of this character is passed through the magnetic focusing field the concentration of the beam is, of course, destroyed. Those electron paths which are substantially parallel to the field are affected by it in a normal way, and are brought to a focus in the plane of the aperture, traversing the paths which are little different from what they would be were the electrostatic field straight and uniform. The peripheral electrons, however, cut sharply across the focusing field, and are accordingly deflected in spiral paths and brought into tangency with the line of magnetic force through their origin considerably closer to their source than they otherwise would be. They are, however, deflected from the aperture, and since they do not enter into the picture signal their ultimate paths and points of collection are immaterial.

When the deflecting field becomes effective, however, so that the peripheral electrons are passing substantially parallel to the resultant field, these in turn are brought to a focus at the aperture but little affected by the magnetic field, while the central electrons and those from the opposite edge of the cathode cut sharply across the magnetic field and are diverted. The higher mean velocity of these peripheral electrons, due to their quicker acceleration, brings their focal plane closer to the aperture than it would be were they traveling at the same mean velocity as the central electrons.

The effect may be considered from another angle; the magnetic field serves to focus the electron stream, not in a plane, as would be the case were the electrons traveling parallel and with uniform velocity, but in a sharply curved surface which is tangent to the collecting aperture, the curvature and conformation of the focal surface changing constantly as deflection takes place.

Any failure to meet the condition of exact tangency at the point of collection is compensated for by additional depth of focus which results from the convergency of the electron stream. Since the electrons from any elementary area or small group of elementary areas tend to converge, there is no tendency for the electrons from the area under scansion to diffuse and fail to fall within the aperture; the only difficulty which arises from a failure of exact focus is that some of the electrons from adjacent elementary areas will also be collected. The result of a failure of exact focus, therefore, is merely the equivalent of using a slightly larger collecting aperture, and not a tendency toward a dead level of illumination such as would occur if the direction of the electrons were random. A much greater tolerance as to strength of focusing field than would otherwise be the case is therefore permissible.

The strength of the deflecting and focusing fields can likewise be decreased, since the tendency of all of the electrons is to fall into the aperture and it is therefore unnecessary to force the desired electrons into line magnetically, but merely to divert the undesired electrons from the aperture sufficiently so that they will not cause trouble.

In order to determine the correct proportion for an electrode structure, other than the example given, to obtain the effect here described, the best method is one of cut and try. An approximate solution may be obtained mathematically if the effect of necessary incidental structures which destroy symmetry be neglected. The mathematics, however, are extremely complex and the experimental solution is relatively easy. A perfectly plane cathode, without the surrounding flange, gives maximum difference in strength of field between the periphery and the axis of the structure. This arrangement, however, exercises almost no concentrating effect. The deeper the cathode cup, the closer to the emitting surface the point of concentration falls, while the deeper the anode cup the greater the peripheral velocity in comparison to the axial velocity. By laying out graphically a proposed electrode structure, and tracing in the lines of force, the approximate paths of the electrons may be predetermined. The optimum structure may, at the first approximation, be taken as the shallowest cathode cup which will give concentration at the point desired. The spacing between anode and cathode naturally affects this design. Only the final adjustment, in order to get most satisfactory effects, need therefore be constructed and tried.

I claim:

1. The method of electrical picture analysis which comprises the steps of forming an electron stream having the characteristics of an electrical image at its source only, and subjecting said stream to the combined action of electric and magnetic fields, one of said fields being proportioned to direct all electrons component of said stream toward a preselected point of collection, and the other of said fields being proportioned to direct electrons from a single elementary area only of the source toward said point of collection at any one instant and to divert the remainder of the electrons component of said stream from said point.

2. The method of electrical picture analysis which comprises the steps of forming an electron stream having the characteristics of an electrical image at its source only, passing said stream through an electrostatic field proportioned as an electrostatic lens adapted to concentrate said stream at a preselected point of collection, and subjecting said stream to deflecting and focusing magnetic fields, the combined strength of said magnetic fields being merely sufficient to divert from said point of collection those electrons whose paths under the action of the electrostatic field alone would not be substantially parallel to the instantaneous resultant magnetic field.

3. The method of electrical picture analysis which comprises the steps of forming an electron stream having the characteristics of an electrical image at its source only, passing said stream through an electric field of non-uniform gradient toward a substantially axial point of collection, said field being steeper in gradient adjacent the edges of the source than adjacent the center thereof, whereby the peripheral electrons of said stream approach their final velocity more quickly

than the central electrons so that the time of passage of the electrons between source and point of collection is less along peripheral paths than along central paths therebetween, and subjecting said stream to magnetic focusing and deflecting fields to bring electrons from all elementary areas of said source successively in focus at said point of collection.

4. The method of electrical picture analysis which comprises the steps of forming an electron stream having the characteristics of an electrical image at its source only, accelerating all of the electrons of said stream toward a substantially axial point of collection, the initial acceleration of the peripheral electrons of said stream being greater than that of the more central electrons of said stream and the terminal velocities of all of said electrons being substantially equal, and passing said electrons through a substantially constant longitudinal magnetic field and a transverse magnetic field varying in such manner as to bring the paths of electrons from all parts of said source successively parallel with the resultant of said fields.

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