March 3, 1942. D. W. EPSTEIN 2,275,029

CATHODE RAY TUBE

Filed May 31, 1940 2 Sheets-Sheet 1

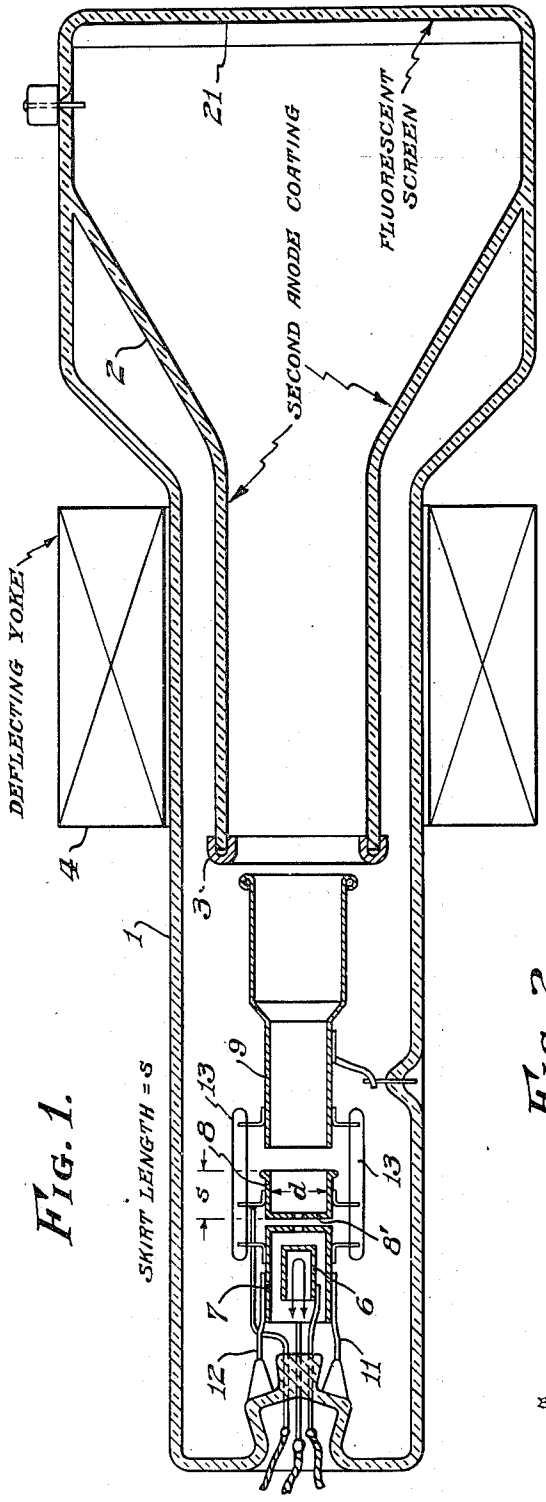


FIG. 1.

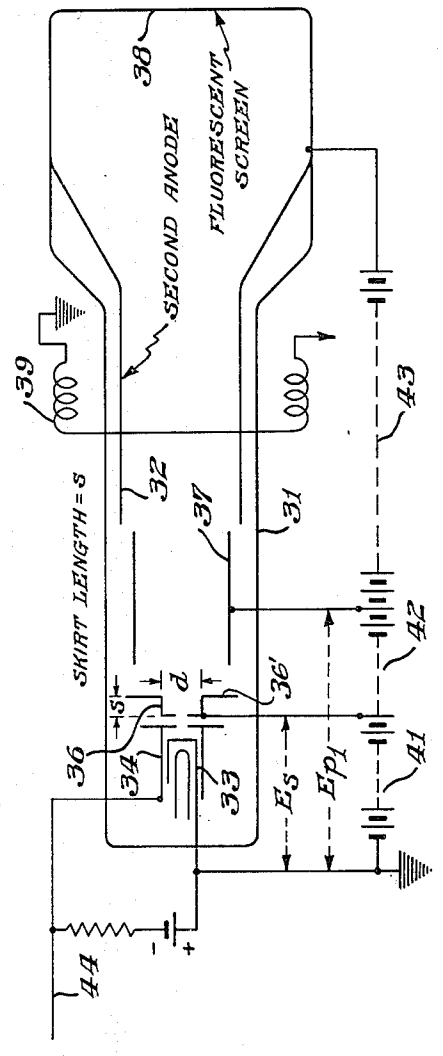


FIG. 2.

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FIG. 3.

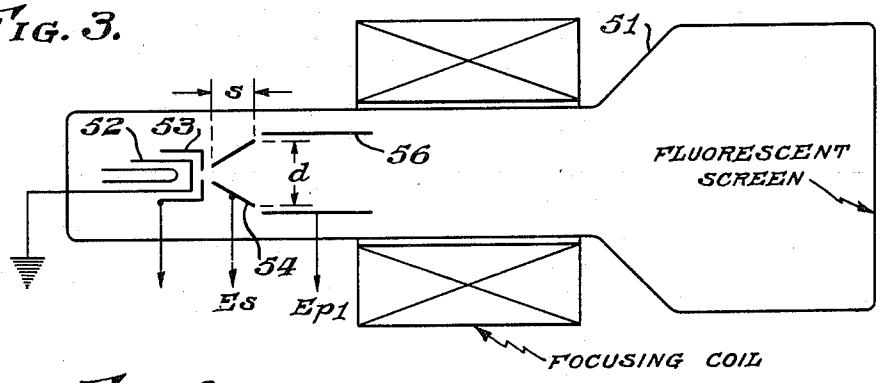
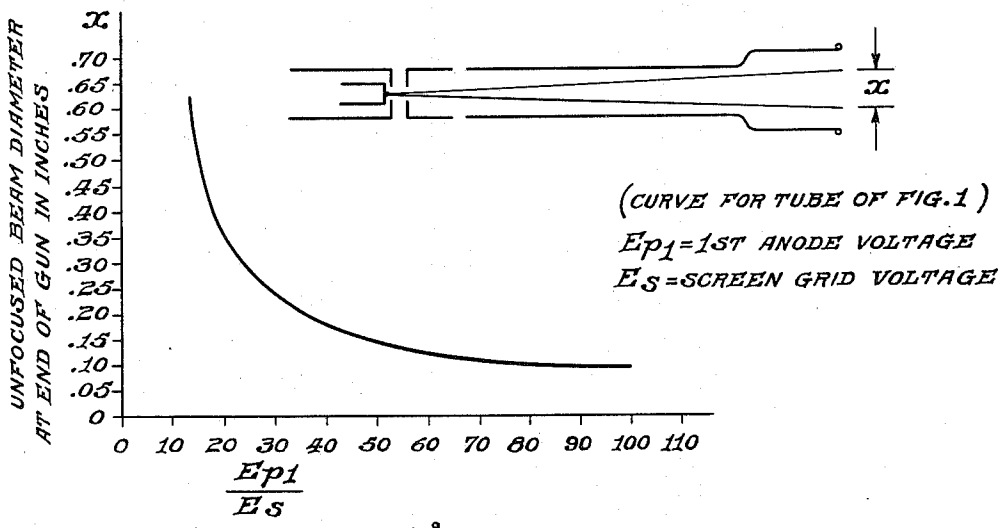


FIG. 4.



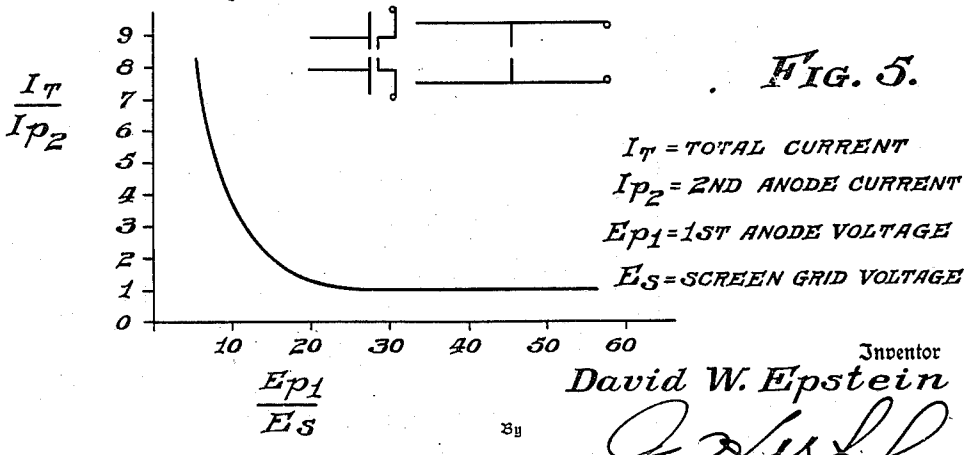


FIG. 5.

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Patented Mar. 3, 1942

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2,275,029

CATHODE RAY TUBE

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Application May 31, 1940, Serial No. 338,058

9 Claims. (Cl. 250—27)

My invention relates to cathode ray tubes and particularly to cathode ray tubes of the projection type which are operated at a high anode voltage.

One of the most commonly used cathode ray tubes at the present time includes two anodes which are generally referred to as the first anode and the second anode. In a tube of this type, the cathode ray is electrostatically focused to a small spot on a fluorescent screen at the end of the tube by a proper adjustment of the ratio of the first anode voltage to the second anode voltage. In these cathode ray tubes as formerly designed, the first anode is struck by some of the electrons of the cathode ray, this resulting in a certain amount of first anode current.

The presence of first anode current greatly increases the difficulty in designing a high voltage television projector tube or the like, since the first anode current will vary with picture signal or with other voltage variations applied to the control grid. The result is that because of the poor voltage regulation in voltage supply units designed to provide a high voltage, such as voltages of the order of 50,000 volts, for example, there is a variation in the first anode voltage and the cathode ray does not remain properly focused on the fluorescent screen.

Furthermore, the cost of a high voltage supply unit increases with any increase in the amount of current it is designed to supply. Thus, if all the current taken at the high voltage is useful current, that is, if it is all beam current, the cost of the voltage supply unit can be made a minimum.

It is sometimes preferred to employ electromagnetic focusing rather than electrostatic focusing in a cathode ray tube. In that case, the tube does not include a second anode. However, the single anode of the electron gun may still be referred to as the "first anode" and it is so designated in the specification and claims. My invention applies to a cathode ray tube of this type as well as to the type first described.

In either of the above-mentioned types of cathode ray tubes, it has been found that the quality of a reproduced picture may be impaired as a result of the beam spot (the spot made on the fluorescent screen by the electron beam) getting large when picture signal drives the control grid to a low negative voltage or to a positive voltage. This increase in spot size is referred to as defocusing of the cathode ray.

One of the objects of my invention is to provide an improved electron gun for a cathode ray tube.

Another object of my invention is to provide an improved cathode ray tube and associated circuit.

Still another object of my invention is to provide an improved cathode ray tube in which there is a large reduction in the amount of defocusing of the cathode ray resulting from variations in the voltage on the control grid.

Still another object of my invention is to provide an improved cathode ray tube and associated circuit so designed that the first anode does not draw any current.

A still further object of my invention is to provide an improved cathode ray tube in which all the current which is drawn from the cathode is useful current whereby for a given beam current the life of the cathode is increased.

In the preferred embodiment of my invention, the electron gun includes a screen grid having a certain ratio of "skirt" length to grid diameter and having a ratio of first anode voltage to screen grid voltage above a certain value. I have found, for example, that by making the screen grid in the form of a cylinder having the ratio of cylinder length (i. e., "skirt" length) to cylinder diameter within certain limits and by having the ratio of first anode voltage to screen grid voltage above a certain minimum value, it is possible to eliminate first anode current and to keep the beam spot small. The axial length of the cylinder, as indicated above, is referred to as the "skirt" length of the screen grid. As will be explained hereinafter. the screen grid need not be in the form of a cylinder but may have various other forms so long as it is provided with a "skirt" of the proper effective length. For instance, the screen grid may be in the shape of a cone.

The invention will be better understood from the following description taken in connection with the accompanying drawings in which

Figure 1 is a view of a cathode ray tube constructed in accordance with one of the preferred embodiments of my invention, the electron gun in this view being drawn full scale,

Figure 2 is a view showing another embodiment of my invention, the electron gun in this view also being drawn full scale,

Figure 3 is a view of another embodiment of my invention in which electromagnetic focusing is employed,

Figure 4 is a curve showing certain characteristics of the tube illustrated in Figure 1, and

Figure 5 is a curve showing certain characteristics of the electron gun accompanying the curve, this gun being similar to the one illustrated in Figure 2.

Referring to the embodiment of my invention shown in Figure 1, there is illustrated a projection type cathode ray tube designed to have a high voltage, such as from 50,000 to 70,000 volts, for example, applied to its second anode. The tube comprises a highly evacuated glass envel-

ope 1 in which there is a reentrant portion 2 for supporting the second anode 3.

The reentrant construction for the second anode is employed to avoid voltage breakdown between the second anode and the deflecting yoke 4 as described and claimed in my copending application Serial No. 302,217, filed October 31, 1939, entitled "Cathode ray tubes," and assigned to the Radio Corporation of America. Such voltage breakdown cannot occur with the reentrant design because of the insulation provided by the high vacuum between the second anode and the deflecting yoke.

The electron gun comprises an indirectly heated cathode 6, a control electrode or grid 7, a screen grid 8, and a first anode 9. The several electrodes are suitably supported in the tube and held in rigid relation with respect to each other by means of supporting wires 11 and 12 and by means of glass beads 13.

At the end of the envelope 1, opposite the electron gun, there is a fluorescent screen 21, which, in the example shown, is coated on the inner surface of the envelope itself. The fluorescent material of the screen 21 preferably has evaporated thereon a thin transparent layer of metal in order to prevent charges from building up on the screen while it is being scanned by the electron beam.

In the specific embodiment of the invention illustrated in Fig. 1, the screen grid 8, like the other tube electrodes, is cylindrical in form. It has a skirt length s and a diameter d as indicated on the drawings. It may be provided with an apertured diaphragm 8' which preferably is located at or near the end of the screen grid facing the control grid 7. It should be mentioned that the aperture in the screen grid is not necessary although it is preferable in most gun constructions.

I have found that by properly proportioning the skirt length s of the screen grid 8 with respect to the screen grid diameter d and by selecting the proper ratio of first anode voltage to screen grid voltage, I can reduce the first anode current to zero and at the same time can obtain a spot size which does not become large when the control grid becomes less negative. In the various tube structures which I have built and tested, I have found that the skirt length s should be greater than $\frac{1}{10}$ the screen grid diameter d but less than 2.5 times the diameter d, and that the ratio of the first anode voltage to the screen grid voltage should be greater than 8 and preferably, in most cases at least, as high as 15 or 20.

The reason for the lower limit on the ratio of first anode voltage to screen grid voltage is that, in order to have zero first anode current without having excessive spherical aberration, it is necessary to keep the beam width or diameter at the end of the first anode below 55 per cent. (preferably below 35 or 40 per cent.) of the first anode diameter. The anode diameter is measured at the end of the anode where the beam width is measured. In order to keep the beam width below this value for gun structures having short first anodes of large diameter, such as the structure illustrated in Fig. 2, for example, a voltage ratio of at least 10 is required. For the particular gun structure shown in Fig. 1, where a longer first anode is employed, the lower limit of the voltage ratio is about 15.

The reason for the upper limit on the length s of the screen grid is that the beam divergence as it enters the screen grid is high so that, in the case of a long screen grid, the beam will be so wide at the screen grid-first anode lens that there will be a large amount of aberration, and the spot will be large.

The lower limit on the screen grid dimension s is due to the fact that for the smaller values of s the gun operates only slightly better than a gun structure which includes the disc screen grid commonly used. It may be noted that the smaller values of s falling within the limits specified may be used to advantage only when the first anode is short, as, for example, when its length is only about one or one and one-half times its diameter. Otherwise, the divergence of the beam would cause the ratio of beam width to first anode diameter to be too large and too much spherical aberration would be introduced.

By employing the screen grid dimensions and the voltage ratio above specified, there is produced an electrostatic lens which is of short focal length on the object or cathode side of the lens. This short focal length is made such that the object is substantially at the focus of the lens whereby there is passed through the first anode a low divergent electron beam which, as indicated in Fig. 4, has a beam diameter x at the end of the first anode. It will be seen that the divergence of the beam is so small that the beam does not strike the first anode. Thus, there is no first anode current.

It may also be noted that the beam width or diameter is no greater than it would be if an aperture were placed in the first anode (as shown in Fig. 5) to limit the beam diameter, as has to be done in other guns, in order to obtain a properly focused spot. As explained in the book, by Maloff and Epstein, published in 1938 by McGraw-Hill and entitled "Electron optics in television," chapter 7, pages 128–133, the beam diameter at the end of the first anode should be kept down to less than 55 per cent. of the first anode diameter to avoid undesirable aberration and below 35 per cent. to avoid aberration entirely. Otherwise, the focusing properties of the first anode-second anode lens will be seriously impaired and a large spot will be produced on the fluorescent screen.

It may be noted that, in the particular tube shown in Fig. 1, the object is the beam "cross-over." The "cross-over" is explained on pages 120 and 121 of the above-mentioned book by Maloff and Epstein.

The geometry of the screen grid determines the curvature or shape of the electrostatic lens while the ratio of first anode voltage to screen grid voltage determines the effective index of refraction. The focal length of the lens, as controlled by the voltage ratio, is determined by the equation

$$\frac{f_1}{f_2}=\sqrt{\frac{E_s}{E_{p1}}}$$

where f_1=object focal length (to left of lens in Fig. 1), f_2=image focal length, E_{p1}=first anode voltage and E_s=screen grid voltage.

In the specific tube shown in Fig. 1, the skirt length s is ¾ of the diameter d. Satisfactory operating voltages are as follows:

Screen grid: +450 volts
First anode: +11,000 volts
Second anode: +56,000 volts

The control grid may be operated at a negative bias of about 100 volts. It will be understood, however, that the bias is preferably made to vary

in accordance with the background of the picture being transmitted.

Reference to Fig. 4 will show that as the ratio of the first anode voltage to the screen grid voltage is increased, the diameter x of the electron beam at the end of the gun decreases. From a voltage ratio of about 20, however, the decrease in beam diameter is not very rapid and it is found that if the tube is operated with a voltage ratio of this order the resulting spot size is entirely satisfactory. It will be evident from the curve that at the lower voltage ratios the beam will diverge enough to permit some of the electrons to strike the first anode and cause a flow of first anode current.

In Fig. 2, there is illustrated another cathode ray tube embodying my invention in which the ratio of skirt length s to screen grid diameter d is less than in the embodiment of Fig. 1. This tube is similar to the one previously described and comprises an evacuated envelope 31 having therein a reentrant second anode 32 and an electron gun comprising a cathode 33, a control grid 34, a screen grid 36 and a first anode 37. The screen grid 36, in this particular tube, has a disc 36' thereon which is provided in this instance for the purpose of facilitating assembly and support of the gun electrodes. It may be omitted if desired, and the screen grid supported as shown in Fig. 1 instead of being supported from the disc 36'.

The disc 36' may have a useful shielding action in certain tubes. For example, if the screen grid diameter is small compared to the first anode diameter, the first anode field is prevented from entering into the region between the control grid and the screen grid by way of the space outside the screen grid. It is desirable to prevent this because otherwise the field between the two grids may be made unsymmetrical due to the supporting wires and/or electrode leads outside the cylindrical electrodes.

A fluorescent screen 38 is located at the end of the tube as indicated.

While two pairs of deflecting coils are ordinarily employed with a tube of this type, in order to simplify the drawing, only one pair of coils is indicated schematically at 39.

The screen grid 36 and the anodes 37 and 32 have positive voltages of the desired values applied thereto from suitable sources which are indicated by way of example as batteries 41, 42 and 43. In practice, of course, high voltage transformers, rectifiers and filters are employed. The picture signal is applied to the negatively biased control grid 34 through an input lead 44.

It will be understood that the circuit connections for the tube of Fig. 1 are the same as those shown in Fig. 2.

In the specific tube construction of Fig. 2, the skirt length s is $\frac{9}{10}$ times the screen grid diameter d. The following electrode voltages have been found to give satisfactory results:

Screen grid : +400 volts
First anode : +11,000 volts
Second anode : +56,000 volts

It will be apparent from an inspection of the curves in Figs. 4 and 5 that the ratio of first anode to screen grid voltage is not critical but that it must be above a certain value.

The curve shown in Fig. 5 applies generally to the above-described embodiments of my invention. It will be noted that above a certain ratio of first anode voltage to screen grid voltage the total current becomes the second anode or beam current. It follows that, above this voltage ratio, there is no first anode current. It is also true, of course, that the tube draws no screen grid current.

The specific curve of Fig. 5 is for the gun structure shown in Fig. 5 (this structure being drawn to scale) where the first anode is provided with an aperture. Because of this aperture, the first anode draws some current at a lower ratio of first anode to screen grid voltage than is the case where the aperture is omitted. It may be noted that in this specific gun structure the size and position of the aperture are such that the beam width at the end of the first anode will be sufficiently small so as not to have the final spot ruined by aberration even though the first anode is drawing current. Generally speaking, in a cathode ray tube embodying my invention, there is no reason for providing the first anode with an aperture since the entire beam would pass through the aperture.

In Fig. 3, there is shown an embodiment of my invention in which the screen grid is conical rather than cylindrical in shape. Also, in this particular embodiment, the second anode is omitted, the desired electron acceleration being obtained by applying the required high voltage to the first anode. The beam focusing in this case is electromagnetic rather than electrostatic.

Referring to Fig. 3, the tube comprises an evacuated envelope 51 having therein an electron gun comprising a cathode 52, a control grid 53, a screen grid 54, and an anode 56. As shown, the screen grid 54 is conical in shape and has an effective skirt length s and a diameter d, the values s and d here corresponding to the values s and d previously referred to in describing Figs. 1 and 2.

It will be understood that the previous statements with respect to the ratio of s to d and with respect to the ratio of first anode voltage to screen grid voltage apply to Fig. 3 as well as to Figs. 1 and 2.

While I have described my invention particularly with respect to cathode ray tubes which are operated with high anode voltages, it should be understood that the invention also applies to the type of tube described in the above-mentioned Maloff and Epstein book and illustrated on page 94, Figure 5.3(*b*). Specifically, the invention applies to a tube in which the final focusing of the beam is obtained by means of a unipotential electrostatic lens rather than by a bipotential lens, such as illustrated in Figs. 1 and 2, or by means of an electromagnetic lens, such as illustrated in Fig. 3. However, in applying the unipotential lens to a cathode ray tube embodying my invention, the potential of the middle electrode is less than that of the end electrodes.

It will be understood from the foregoing that various other modifications may be made in my invention without departing from the spirit and scope thereof.

I claim as my invention:

1. In a cathode ray tube, an electron gun comprising a cathode, a control grid, a screen grid electrode and a first anode positioned in the order named, said screen grid having a substantial longitudinal dimension or skirt length along the longitudinal axis of said gun as compared with the transverse dimension of the screen grid, the ratio of said skirt length to said transverse di-

mension being such that an electrostatic lens is formed having a focus substantially at said cathode when there is applied to said anode a voltage which is at least eight times the voltage which is applied to the screen grid.

2. A cathode ray tube comprising a cathode, a control electrode, a screen grid and an anode located along an axis in the order named, said screen grid having in the direction of said axis a longitudinal dimension or skirt length greater than one-tenth the inner transverse dimension of said screen grid and less than two and one-half times said transverse dimension, and the ratio of first anode voltage to screen grid voltage being greater than eight.

3. The invention according to claim 2 wherein the ratio of skirt length to transverse screen grid dimension and the ratio of anode voltage to screen grid voltage are such that there is substantially no flow of current to said anode.

4. The invention according to claim 2 wherein the ratio of skirt length to transverse screen grid dimension and the ratio of anode voltage to screen grid voltage are such that there is formed an electrostatic lens having a focus substantially at said cathode.

5. The invention according to claim 2 wherein the ratio of skirt length to transverse screen grid dimension and the ratio of anode voltage to screen grid voltage are such that the electron beam width at the end of the first anode is less than 55 per cent. of the transverse dimension of the anode at said end.

6. In combination, a cathode ray tube comprising a cathode, a cylindrical control electrode, a cylindrical screen grid said screen grid having a length greater than one-fourth its diameter and less than one and one-half times said diameter, and a cylindrical anode located along an axis in the order named, and means for applying positive voltages to said anode and said screen grid with the ratio of anode voltage to screen grid voltage greater than eight.

7. In combination, a cathode ray tube comprising a cathode, a cylindrical control electrode, a cylindrical screen grid and a tubular anode located along an axis in the order named, said screen grid having a length greater than one-tenth of its inner diameter and less than two and one-half times said diameter, and means for supplying positive voltages to said anode and to said screen grid with the ratio of anode voltage to screen grid voltage greater than eight.

8. The invention according to claim 7 wherein the ratio of screen grid length to screen grid diameter and the ratio of anode voltage to screen grid voltage are such that the electron beam width at the end of the anode is less than 55 per cent. of the anode diameter at said end.

9. A cathode ray tube comprising a cathode, a control electrode, a screen grid and an anode located along an axis in the order named, said screen grid having in the direction of said axis a longitudinal dimension or skirt length greater than one-fourth the inner transverse dimension of said screen grid and less than one and one-half said transverse dimension, and the ratio of first anode voltage to screen grid voltage being greater than eight.

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