

Dec. 13, 1938.

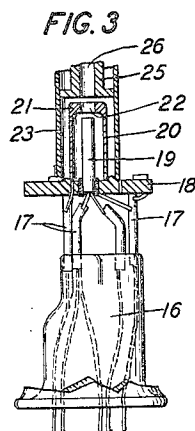
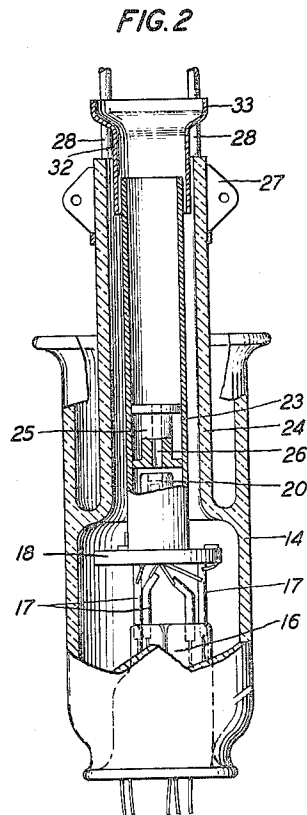
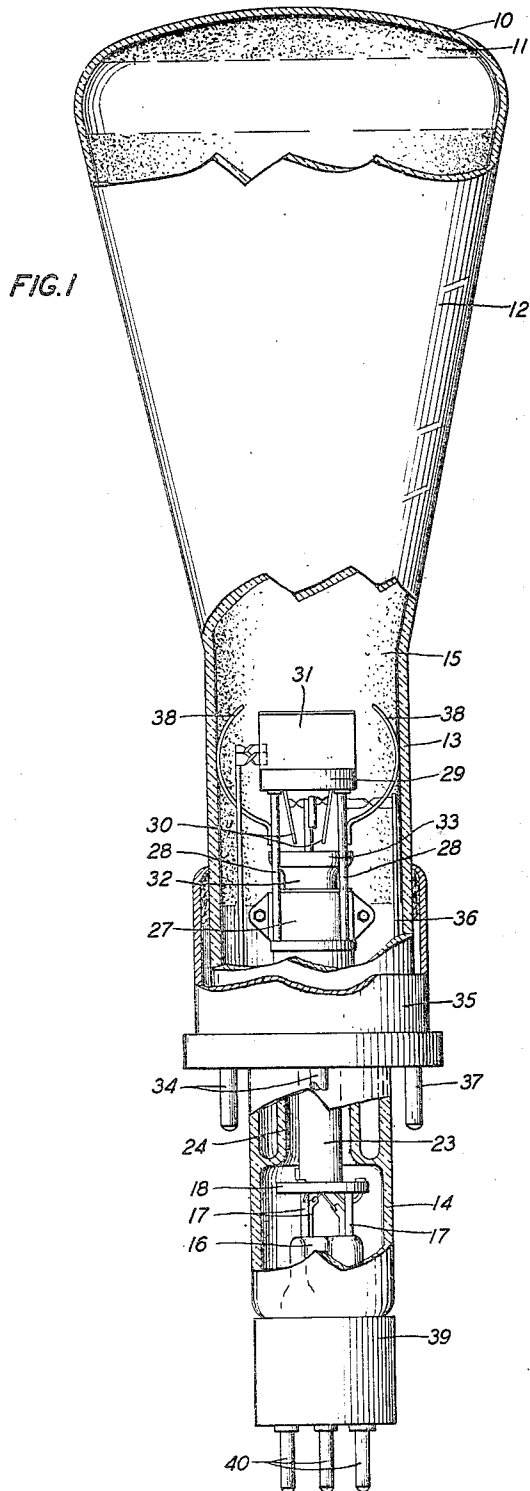
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2,139,678

ELECTRON DISCHARGE DEVICE

Filed Oct. 10, 1936

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 4

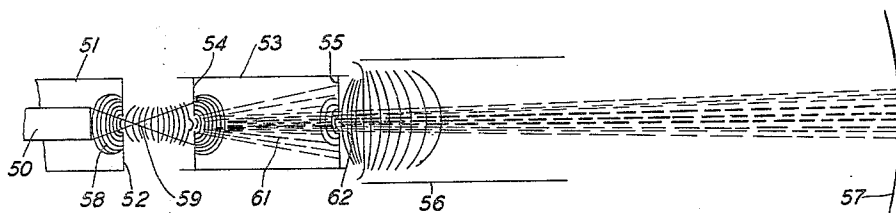


FIG. 5

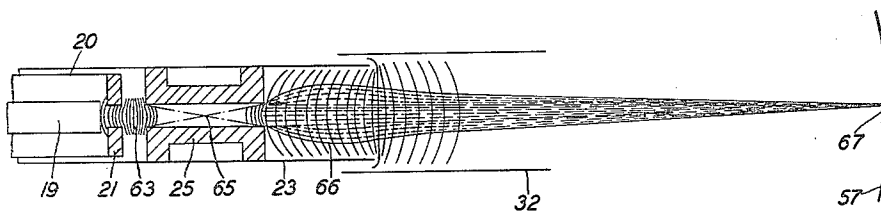


FIG. 6

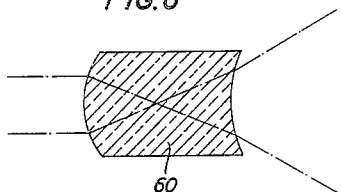


FIG. 7

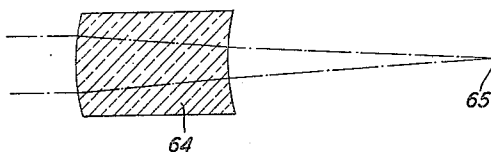
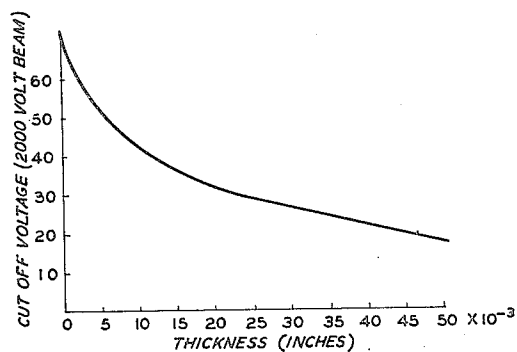


FIG. 8



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ELECTRON DISCHARGE DEVICE

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Application October 10, 1936, Serial No. 104,963

17 Claims. (Cl. 250-162)

This invention relates to electron discharge devices of the cathode ray type in which an electron stream is projected toward a screen at the end of the device.

In the usual cathode ray tube the electron stream travels a considerable distance to the screen in order that the stream may be deflected over the complete area of the screen. The length of the projection path of the stream and improper focussing cause divergence of the stream which results in producing a large diameter spot of low actinic value on the screen. Such a spot is highly inefficient for photographic purposes or for visual indication of the electrical phenomena or images to be observed.

An object of this invention is to concentrate the electrons in the cathode ray or stream and increase the efficiency and brilliance of the spot on the screen.

A further object of the invention is to improve the focussing lens system of cathode ray discharge devices.

In accordance with one aspect of this invention as applied to a "Braun" type device, an enclosing vessel is provided with a fluorescent screen on one end, an electron gun at the other end for projecting a stream of cathode rays along the axis of the vessel, and a set of deflector plates intermediate the gun and screen for sweeping the ray over the whole area of the screen.

The electron gun forms the basis of this invention and comprises an electron source or cathode, a control electrode coaxially surrounding the cathode and having a thick end portion provided with an aperture, an elongated cylindrical focussing electrode, coaxial with the cathode and control electrode, and an accelerating electrode, coaxial with and overlapping the end of the focussing electrode. The focussing electrode is provided with a collimating member or plug with a central passageway of the same diameter as and coaxial with the aperture in the control electrode. This member is positioned so that one end is adjacent the thick end portion of the control electrode and the other end terminates about the mid-point of the focussing electrode.

A feature of the invention relates to the relationship of the various elements of the electron gun to insure the proper focussing of the electron stream and to eliminate dispersion effects of the electrons. The general formula for producing a brilliant spot of high efficiency pertains to the dimensions and spacial relation of the elements in which the thickness of the end portion of the control electrode should be about one-half the diameter of the aperture in the electrode and

also bear a relation to the cathode spacing with respect to the end portion of the control electrode, namely about three times the cathode spacing. The collimating member is provided with a central passageway of the same diameter as the aperture in the control electrode and is arranged in alignment therewith, the end face of the member adjacent the control electrode being spaced therefrom a distance comparable with the diameter of the passageway while the opposite end face of the member should terminate approximately at a point one-half the length of the cylindrical focussing electrode. In addition, an accelerating electrode which overlaps the end of the focussing electrode completes the series of electron lenses of the electron gun assembly.

Other features of the invention will be apparent from the following detailed description when considered in connection with the accompanying drawings.

Fig. 1 illustrates in elevation a cathode ray discharge device embodying features of this invention with portions of the enclosing vessel broken away to show the internal structural details;

Fig. 2 is an enlarged cross-sectional view of the electron gun assembly according to this invention;

Fig. 3 is another enlarged view of the supporting stem and a portion of the electron gun shown in cross-section to illustrate the spacial relationship of the elements according to this invention;

Fig. 4 is a diagrammatic view showing the relation of the elements and the general focussing effect produced in a device of the prior art;

Fig. 5 is another diagrammatic view showing the relation of the elements and the focussing effect produced in the device of this invention;

Fig. 6 shows diagrammatically an optical lens and the focussing effect thereof equivalent to the electron lens adjacent the cathode of the diagram shown in Fig. 4;

Fig. 7 illustrates the complementary optical lens of the cathode lens according to this invention, as shown in Fig. 5; and

Fig. 8 is a graphic curve of the relationship of the control electrode thickness to the cut-off voltage of the electrode for a given set of conditions.

Referring to the drawings, and Figs. 1, 2 and 3 particularly, the cathode ray discharge device of this invention embodies an elongated enclosing vessel having a dome portion 10 provided with a fluorescent coating 11 on the interior thereof

which functions as the screen of the device. The dome is joined to a long, tapered portion 12 which continues to a cylindrical portion 13 and the cylindrical portion is joined to a tubular extension 14, of smaller diameter which supports the electron gun embodying the features of this invention. The tapered portion 13 and the cylindrical portion 14 are provided with an internal non-reflecting coating 15, such as graphite, which also may serve as an accelerating anode or electrode in the operation of the device.

The electron gun located in the tubular extension 14 and projecting into the cylindrical portion 13 is arranged with its axis coincident with the axis of the enclosing vessel so that the stream of electrons emanating from the gun impinges on the screen or fluorescent coating 11 as a sharply defined and brilliant spot. The gun is supported by a reentrant stem 16 sealed to the end of the extension 14 and comprises a plurality of short rods 17 which are sealed in the stem at one end and carry an insulating platform 18 at the other end. The center of the platform is drilled to receive an indirectly heated cathode 19. This cathode is formed of a tubular metallic shell closed at the upper end and provided with an internal heater element for heating the shell by conduction. The closed end of the shell of the cathode is coated with electron emissive material which serves as a source of electrons for producing the cathode rays or stream directed toward the screen.

The cathode 19 is surrounded by a coaxially arranged control electrode having a cylindrical portion 20 secured to the platform and an apertured disc portion 21. The disc portion is relatively thick in comparison to the portion 20 and the thickness bears a definite relation to the size of the aperture 22 and the spacing between the inner surface of the disc portion 21 and the emitting surface of the cathode 19. For a specific set of operating conditions, the ratios of focussing disc thickness are approximately $\frac{1}{2}$:1 with respect to the aperture diameter and 3:1 with respect to the cathode spacing.

The control electrode is surrounded by an elongated tubular metallic focussing electrode 23 which is coaxially mounted on the platform 18 and extends almost to the top of an internal tubular glass member 24 which is fused to an intermediate portion of the extension 14. The focussing electrode is provided with a collimating member 25, machined in the form of a spool, to reduce its mass and facilitate its attachment to the electrode 23. The spool ends are substantially the same diameter as the internal diameter of the focussing electrode 23 and the spool is secured thereto, for instance, by welding through the wall of the tubular member 23. The collimating member is drilled to provide a central passageway 26 having a diameter the same as the aperture diameter of the control disc 21 and is mounted in the electrode 23 so that the spool end adjacent the control electrode is spaced therefrom approximately a distance slightly less than the diameter of the passageway 26 while the opposite spool end is situated approximately at the medial point of the length of the electrode 23.

The internal glass member 24 forms a support for an accelerating electrode and the deflector plate assembly which consists of a clamping collar 27 embracing the end of the glass member 24 and supporting four rods 28 attached to an apertured platform 29 which supports a pair of

downwardly extending deflector plates 30 and a pair of upwardly extending plates 31. A tubular metallic accelerating electrode 32 is positioned intermediate the platform 29 and the collar 27 and is provided with an enlarged throat 33 which engages the four rods 28 and is welded thereto at the contacting points. The accelerating electrode 32 is of such a length and diameter that it overlaps the end of the focussing electrode 23 within the glass member 24. Suitable conductors are attached to the deflector plates and brought out through the glass vessel to terminals 34 on a base 35 which surrounds the end of the cylindrical portion 13 of the vessel. A separate conductor 36 is connected to an external terminal 37 and also attached to a rod 28 for applying an accelerating positive voltage to the electrode 32. This voltage is also supplied to the conducting coating of graphite 15 which serves as an additional electrode for accelerating the flow of the electron stream toward the screen 11. This potential is applied to the coating through the frictional contact of the spring fingers 38 which extend from the rods 28. A base 39 is provided on the end of the extension 14 and carries terminals 40 for the heater element, cathode, control electrode and the focussing electrode of the electron gun.

The fabrication of the assembly of the device of this invention may be performed in accordance with the disclosure of an application of D. A. S. Hale, Serial No. 104,937, filed October 10, 1936.

The correlation of the various elements of the discharge device for increasing the efficiency of the electron stream to produce a brilliant spot of high actinic value on the screen may be better understood by a comparison of the diagrams shown in Figs. 4 and 5 and the graphic representations of the lenses in Figs. 6 and 7. The brilliance of the fluorescent spot on the screen is a function of the number of electrons striking the screen per unit area and the problem therefore is to increase the number of electrons reaching the screen and to decrease the size of the spot.

In the diagram shown in Fig. 4, a cathode 50 is surrounded by a control electrode 51 having a thin apertured disc closure 52 which is spaced a considerable distance from the cathode. A tubular focussing electrode 53 having apertured baffles 54 and 55 at opposite ends is spaced beyond the control electrode 51 and this is followed by an accelerating electrode 56 of larger diameter, all the electrodes being coaxial for projecting electrons to the screen 57. The focussing electrode and the accelerating electrode are supplied with successively increasing positive potentials to pull electrons from the cathode and to accelerate their travel to the screen.

In such a device there is a very steep potential gradient between the control electrode 51 and the focussing electrode 53 which supplies the field for pulling electrons from the cathode. This produces very sharply curved equipotential field lines 58 in and around the aperture of the disc closure 52 and the baffle 54. This condition together with the fact that the electrons from the cathode enter this highly distorted field at low velocity gives rise to a very short focal length lens, in the region between the cathode and the aperture in disc 52 which is comparable to the optical lens 60 shown in Fig. 6. As the cathode 50 is located beyond the focal length of the lens from the control disc 52, the electrons will pass through a focal point 59 beyond the control disc

52 and diverge, a large portion of the electrons being intercepted by the surface of the baffle 54 of the focussing electrode. The number of electrons able to enter the aperture in the baffle is greatly diminished and consequently the efficiency of the cathode stream is impaired. Furthermore, the diverging beam of electrons entering the focussing electrode through the baffle aperture results in further loss of efficiency due to the spreading electrons 61 striking the surface of the baffle 55 and only the paraxial rays are able to continue to the screen. The proximity of the accelerating electrode 56 to the baffle 55 of the focussing electrode gives rise to an accelerating field 62 of high intensity, practically at the exit of the baffle aperture. This field produces a lens action but the distance which the electrons travel through the field is so short that only the paraxial rays contribute to a spot of low actinic value while the divergent rays produce a foggy halo around the spot.

The diagram of Fig. 5 illustrates the focussing electron lens system of the device of this invention. In this arrangement the field between the aperture of the control disc 21 and the cathode 19 is much less sharply curved as shown by the equipotential field lines 63. Consequently the focal length of the lens is increased, and since the cathode is located very close to the aperture, the electrons are not brought to a focus in the field near the disc. Such an electrical lens compares with an optical lens 64, shown in Fig. 7, through which the focal point 65 is carried into the collimating member 25. However, the length of this member forms a long zone of zero potential in which the electrons travel substantially in lines parallel to the axis. The smooth bore of the collimating member and the thick focussing disc also reduce the probability of distortion which might arise from secondary emission, or from roughness or burrs on the edges of the apertures such as usually occur with thin baffles or discs.

When the electron stream emerges from the collimating member 25, it enters the accelerating field 66, which because of the length and curvature of the field, produces a convergence of the electron stream. The electrons of greatest divergence are subject to the greatest converging influence, so the tendency is for most of the electrons which emerge from the collimating member to be brought to a sharp focus 67 at the screen 57. It is evident that the efficiency of the fluorescent spot is extremely high since the proportion of electrons emitted by the cathode which actually arrive at the screen is a measure of the efficiency of the focussing system in the device of this invention. Furthermore, the area of the fluorescent spot is small so that the actinic value and brilliance are high due to the concentration and high velocity of a large number of electrons in a given area of the screen.

A specific example of the arrangement of the focussing system for an operating range between 1000 to 5000 volts applied to the focussing electrode 23 of this invention may include the following dimensions. The cathode diameter is .065 inch and the coated end is spaced from the inner surface of the thick disc closure of the control electrode a distance of .010 inch. The thickness of the disc closure 21 is .030 inch while the aperture diameter is .063 inch. The diameter of the focussing electrode 23 is .411 inch and the length is 2½ inches. The collimating spool 25 is 1 inch long with a bore having a diameter of .063 inch,

the same as the thick disc aperture. The spacing between the lower end of the collimating spool and the control electrode is .040 inch and the other end terminates approximately at the center point of the length of the focussing electrode or 1.625 inches from the top thereof.

The focussing system of this invention is also capable of use in television devices in which the picture currents are applied to the control electrode for modulating the electron stream projected toward the screen. The cut-off voltage, or the modulator potential required to suppress the stream in the case of producing black areas on the screen, may be regulated or adjusted by the thickness of the disc closure 21 of the electrode 20, as shown by the curve in Fig. 8 so that it is possible to secure low values of cut-off voltage depending on the thickness of the modulator electrode disc closure.

While the invention has been disclosed with respect to a particular embodiment in Fig. 1, it is, of course, understood that various modifications may be made in the detailed arrangement and dimensions of the elements of the focussing system of this invention and therefore the scope of the invention should be determined in accordance with the appended claims.

What is claimed is:

1. An electron discharge device comprising a vessel having a fluorescent screen on one end, an electron source at the other end for projecting a stream of electrons to said screen, and a focussing electrical lens system interposed between said source and said screen, said lens system including a control electrode having an apertured thick disc portion before said source, a tubular focussing electrode associated with said control electrode, and an elongated collimating member provided with a bore coaxial with the aperture in said disc portion, located within said tubular electrode and spaced from said disc portion at a distance less than the diameter of the aperture therein.
2. An electron discharge device comprising a vessel having a fluorescent screen on one end, an electron source at the other end for projecting a stream of electrons to said screen, and a focussing electrical lens system interposed between said source and screen, said lens system including a control electrode enclosing said source and having a thick end portion provided with a central aperture in alignment with said source, a tubular focussing electrode surrounding said control electrode, and a collimating member extending along the interior of said focussing electrode intermediate the ends thereof and provided with a bore coaxial with the aperture in said thick end portion.
3. An electron discharge device comprising a vessel having a fluorescent screen on one end, an electron source on the other end for projecting a stream of electrons to said screen, and a focussing electrical lens system interposed between said source and said screen, said lens system including a control electrode surrounding said source and having a thick end portion provided with a central aperture in alignment with said source, an elongated hollow focussing electrode surrounding said control electrode and arranged concentric therewith, and a collimating member within said focussing electrode provided with a bore coaxial with the aperture in said thick end portion.
4. An electron discharge device comprising a vessel having a fluorescent screen on one end, an

electron source on the other end for projecting a stream of electrons to said screen, and a focussing electrical lens system interposed between said source and said screen, said lens system including a control electrode having an apertured thick disc portion before said source, an elongated tubular focussing electrode surrounding said control electrode, and an elongated collimating member within said focussing electrode provided with a bore coaxial with the aperture in said disc portion.

5. An electron discharge device comprising a vessel having a fluorescent screen on one end, an electron source at the other end for projecting a stream of electrons to said screen, and a focussing electrical lens system interposed between said source and said screen, said lens system including a control electrode having an apertured thick disc portion before said source, a tubular focussing electrode having one end surrounding said control electrode, a collimating member within said focussing electrode provided with a bore coaxial with the aperture in said disc portion, and an accelerating electrode adjacent the opposite end of said tubular electrode.

6. An electron discharge device comprising a vessel having a fluorescent screen on one end, an electron source at the other end for projecting a stream of electrons to said screen, and a focussing electrical lens system interposed between said source and said screen, said lens system comprising a cylindrical control electrode having an apertured thick disc portion before said source, an elongated tubular focussing electrode having a portion coextensive with said control electrode, a collimating member within said focussing electrode provided with a bore coaxial with and closely adjacent the aperture in said disc portion, and an accelerating electrode having a portion overlapping said tubular focussing electrode.

7. An electron discharge device comprising a vessel having a fluorescent screen on one end, an electron source at the other end for projecting a stream of electrons to said screen, and a focussing electrical lens system interposed between said source and said screen, said lens system including a control electrode having an apertured thick disc portion before said source, an elongated tubular focussing electrode coaxial with said control electrode, and an elongated spool-shaped metallic member having its opposite ends secured to the inner surface of said focussing electrode and closely spaced with respect to said disc portion and having an axial bore of the same diameter as the aperture in said control electrode.

8. An electron discharge device comprising a vessel having a fluorescent screen on one end, an electron gun at the other end including an emissive cathode, a focussing electrode, a control disc arranged close to said cathode and having a thickness comparable to three times the spacing distance of said cathode from said disc and provided with an aperture through which the electrons are projected toward said screen, and collimating means within said focussing electrode having one end closely adjacent said control disc and also having a bore in alignment with the aperture in said control disc.

9. An electron discharge device comprising a vessel having a fluorescent screen on one end, an electron gun at the other end including an emissive cathode, a focussing electrode, a control disc arranged close to said cathode and having a

thickness comparable to three times the spacing distance of said cathode from said disc and provided with an aperture through which the electrons are projected toward said screen, and collimating means within said focussing electrode having a bore in alignment with the aperture in said control disc, said means having one end spaced from said control disc less than the bore diameter and the other end located substantially at the medial point of said focussing electrode.

10. An electron projection device comprising an enclosing vessel, a screen at one end of said vessel, and an electron gun at the other end thereof for concentrating a stream of electrons to a bright spot on said screen, said gun including an electron emitting source, an apertured control element, an elongated tubular focussing electrode, and an elongated collimating element within said electrode, said control element having a disc portion of a thickness substantially equivalent to half the diameter of the aperture therein, and said source being relatively close to the surface of said control element and in axial relation thereto.

11. An electron projection device comprising an enclosing vessel, a screen at one end of said vessel, and an electron gun at the other end thereof for concentrating a stream of electrons to a bright spot on said screen, said gun including an electron emitting source, a control element having an apertured disc portion, an elongated tubular focussing electrode, and a collimating element within said electrode, said source being relatively close to the inner surface of the disc portion of said control element and in axial relation thereto, and the ratio of element thickness to electron source spacing being approximately 3 to 1, to regulate the cut-off voltage of said control element.

12. An electron projection device comprising an enclosing vessel, a screen at one end of said vessel, and an electron gun at the other end thereof for concentrating a stream of electrons to a bright spot on said screen, said gun including an electron emitting source, an apertured control element, an elongated tubular focussing electrode, and a collimating element within said electrode, said collimating element being in the form of a metallic plug having its ends engaging the electrode wall and having a central aperture coincident with the control element aperture, the length of said collimating element being approximately half the distance from the control element to the end of said electrode nearest said screen.

13. A cathode ray projection device comprising an enclosing vessel, a fluorescent screen at one end, and an electron gun at the other end for producing a brilliant spot of small area on said screen, said gun including an equipotential cathode having the end thereof coated with electron emissive material, a cylindrical electrode surrounding said cathode having an apertured disc closure portion, said disc having a thickness ratio of 3 to 1 with respect to the space intervening between the cathode end and said disc closure and a ratio of $\frac{1}{2}$ to 1 with respect to the aperture diameter, said diameter being substantially the same as the diameter of the end of said cathode, an elongated metallic focussing electrode of tubular form extending beyond said disc closure and coaxial therewith, a collimating plug in said electrode having a long bore coaxial with said disc portion, and an accelerating electrode

of larger diameter than said elongated electrode adjacent the end thereof.

14. A cathode ray projection device comprising an enclosing vessel, a fluorescent screen at one end, and an electron gun at the other end for producing a brilliant spot of small area on said screen, said gun including an equipotential cathode having the end thereof coated with electron emissive material, a cylindrical control electrode surrounding said cathode having an apertured disc closure portion, said disc having a thickness ratio of 3 to 1 with respect to the space intervening between the cathode end and said disc closure and a ratio of $\frac{1}{2}$ to 1 with respect to the aperture diameter, an elongated metallic focussing electrode of tubular form extending beyond said control electrode and coaxial therewith, a collimating member within said focussing electrode having a long bore coaxial with said disc portion, said member having one end spaced from said control electrode less than the bore diameter and the other end located substantially at the medial point of said focussing electrode and an accelerating electrode having a portion overlapping the end of said elongated focussing electrode.

15. An electron beam projection device comprising an elongated enclosing vessel, an electron gun at one end of said vessel for projecting a stream of electrons toward the other end thereof, said gun including an electron emitting source, a control electrode having an apertured disc portion surrounding said source, an elongated tubular focussing electrode adjacent said control electrode, and an elongated collimating element within said electrode, said control disc portion having a thickness substantially equivalent to

half the diameter of the aperture therein, and said source being relatively close to the surface of said control element and in axial relation thereto.

16. An electron beam projection device comprising an enclosing vessel, an electron gun mounted in one end thereof for projecting a stream of electrons toward the other end, said gun comprising an electron source, and a focussing electrical lens system, said lens system including a control electrode surrounding said source and having a thick end portion provided with a central aperture in alignment with said source, an elongated hollow focussing electrode surrounding said control electrode and arranged concentric therewith, and a collimating member within said focussing electrode provided with a bore coaxial with the aperture in said thick end portion.

17. An electron beam projection device comprising an elongated vessel, an electron gun mounted in one end of said vessel for projecting a stream of electrons toward the other end thereof, said gun including an emissive cathode, a focussing electrode, a control disc arranged close to said cathode and having a thickness comparable to three times the spacing distance of said cathode from said disc and provided with an aperture through which the electrons are projected, and a collimating member within said focussing electrode having a bore in alignment with the aperture in said control disc, said member having one end spaced from said control disc at a distance less than the bore diameter and the other end located substantially at the medial point of said focussing electrode.

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