Nov. 14, 1944. G. LIEBMANN 2,362,908

CATHODE RAY TUBE

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FIG. 1.

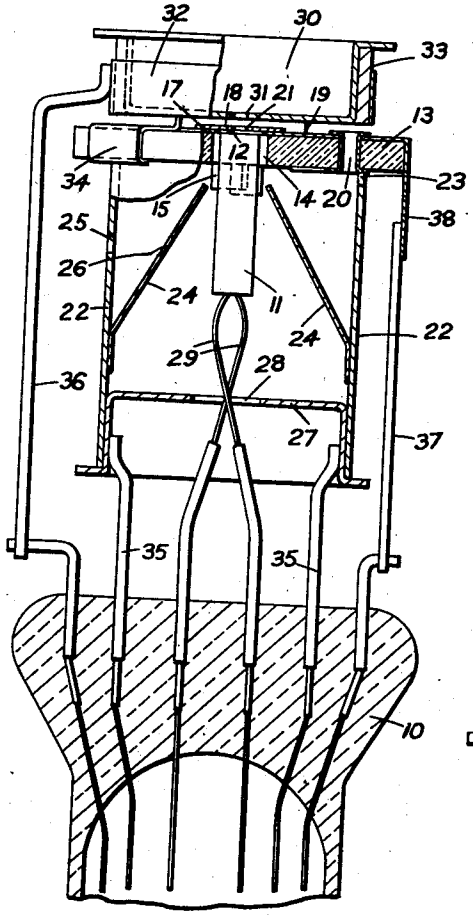


FIG. 2.

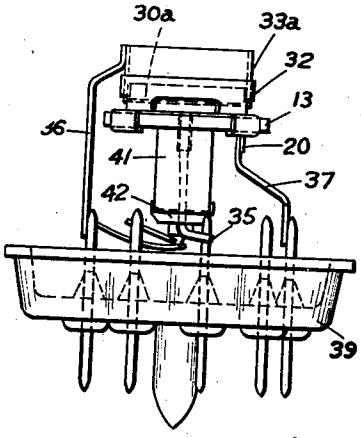


FIG. 3.

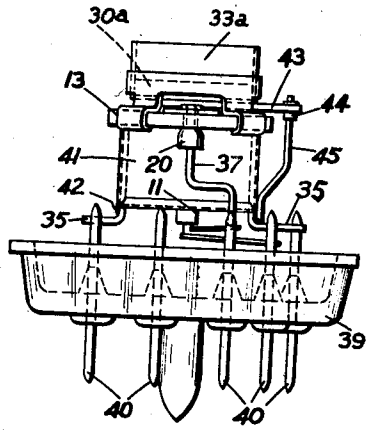


FIG. 4.

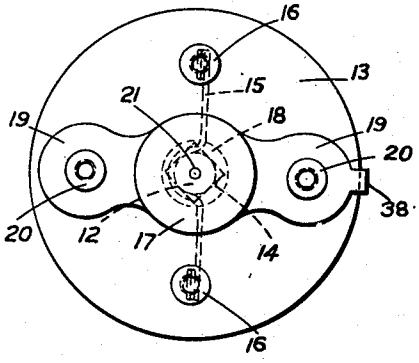
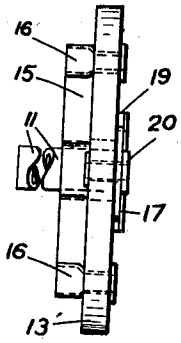


FIG. 5.



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FIG. 6.

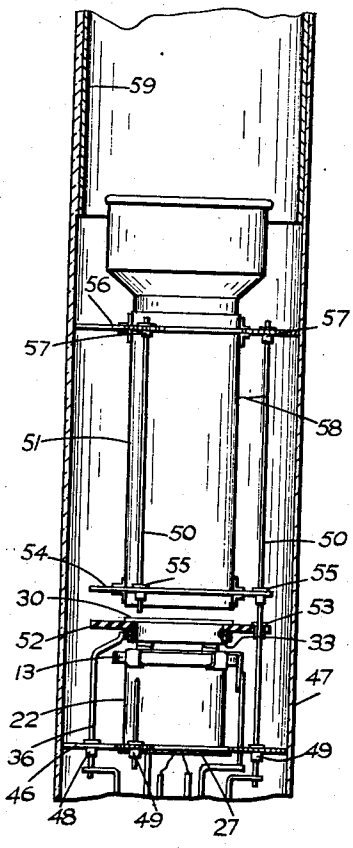


FIG. 8.

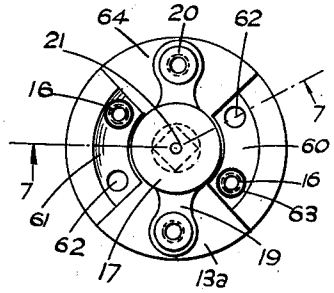


FIG. 9.

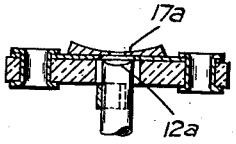


FIG. 10.

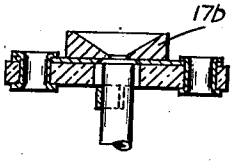


FIG. 7.

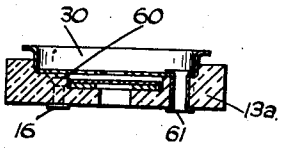
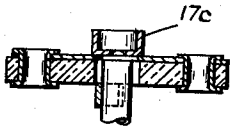


FIG. 11.



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Patented Nov. 14, 1944 2,362,908

UNITED STATES PATENT OFFICE

2,362,908

CATHODE RAY TUBE

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Application November 10, 1943, Serial No. 509,745
In Great Britain November 2, 1942

16 Claims. (Cl. 250—162)

The present invention relates to cathode ray tubes. The invention is particularly applicable to cathode ray tubes in which a very fine trace is required and where the modulating frequency is very high, although it can also be applied to other cathode ray tubes.

In cathode ray tubes the spot producing a trace on the screen is usually generated by imaging the cathode or a "crossover" of the electron beam situated near the cathode, electron optically on to the screen. The intensity of the spot is modulated by applying a suitable voltage between the modulating electrode and the cathode. If a very fine spot is required, the diameter of the crossover must be very small which in turn necessitates a small diameter of the hole in the modulating electrode. It is found experimentally that the current delivered into the electron beam is reduced by a factor of approximately 100 if the diameter of the hole in the modulating electrode is reduced by a factor of 2, all other dimensions and voltages remaining the same. The reason for this enormous change of beam current is the change of field penetration in addition to the change of cross-sectional area.

One object of the present invention is to provide means to scale the critical dimensions, cathode-grid clearance, anode-grid clearance and grid thickness, down in such a way that a field near the cathode is produced which is sufficiently strong to deliver an adequate electron current into the beam. Another object is to provide a simple and sturdy structure by which the necessary fine dimensions and interelectrode spacings may be readily achieved and accurately maintained, and which has the further advantage of a very small capacity between the modulating electrode and all other electrodes, which is a very important property if the cathode ray tube is to be modulated at a very high frequency.

Although the structure according to this invention is especially designed and found particularly useful for constructing cathode ray tubes producing a very fine trace and operating with very high frequency modulation, it has advantages in tubes of other types and with less small electrode clearances, particularly where constancy of clearances and a compact and sturdy construction are important or desirable.

In order that the invention may be more fully understood, reference is made in the following description to the accompanying drawings, in which

Fig. 1 is a view of an electrode structure made in accordance with the invention, certain parts being shown broken away and shown in section for clarity of illustration;

Figs. 2 and 3 are two views taken at right angles to each other of a modification of the structure of Fig. 1;

Figs. 4 and 5 are respectively a plan view and a side view of the cathode-grid assembly;

Fig. 6 is a fragmentary view partly in section, showing the neck of a cathode ray tube containing an electrode system embodying the invention;

Figs. 7 and 8 illustrate a modification with reference to the anode assembly, Fig. 8 showing a plan view of a cathode-grid assembly and Fig. 7 showing a section on the line 7—7 of Fig. 8 with an anode added;

Figs. 9, 10 and 11 are similar cross-sectional views illustrating mainly modifications in the grid form.

For clearness, the elements are shown greatly enlarged in all the figures, except Fig. 6 in which the parts are shown approximately one and a half times full size. In all the figures, like reference characters designate identical or similar parts.

Referring to Fig. 1, the electrode system therein depicted is mounted on a glass stem or pinch 10 for insertion and sealing in the neck of a cathode ray tube. The cathode is in the form of a nickel cylinder or tube 11 which is open at its lower end and has a plane closed top end 12 coated with a suitable electron emissive material forming the cathode proper. The cathode is indirectly heated by an internal heating filament (not shown) within the cathode tube 11. A disc 13 of insulation, preferably ceramic, and specifically porcelain, although another suitable material such as mica, alumina or quartz may be employed, has a central hole 14 which receives the cathode tube 11 inserted therein such that the coated end 12 thereof is flush or coplanar with the upper face of the disc 13. As more clearly shown in Figs. 4 and 5, the cathode tube 11 is fixed, very near to its coated end, to the disc 13 by means of a strip 15 of metal of poor thermal conductivity, for instance, nichrome, which abuts on edge against the underside of the disc 13 and has a semi-circular loop which embraces the cathode tube 11 and is welded to it. The ends of the strip 15 are welded respectively to the squashed and flattened ends of two eyelets 16 which are inserted through diametrically opposed holes provided in the disc 13 near its outer edge. The diameter of the cathode tube 11 and the size of the hole 14 in the disc 13 are such that the cathode tube fits fairly tightly into the hole 14, so that the cathode tube is fixed by the described construction in a very rigid way and once assembled properly cannot move under heat expansion as such expansion takes place towards the open end of the tube 11. Although the loss of heat from the cathode by contact with the disc 13 is not serious owing to the very poor thermal conductivity of the material of the disc, this loss of heat can

be still further reduced to a negligible amount by reducing as far as possible the area of contact between the disc and tube, while of course still maintaining the close fit of the tube in the disc. This may be achieved by making the centre hole 14 of the disc of such a different shape from the cross-sectional shape of the cathode tube 11 that contact is established only at a number of points; for instance, the centre hole 14 of the disc may conveniently be made a square one, as shown in Fig. 4, such that the sides of the hole form tangential planes to the cathode tube 11, making a four-point contact.

The modulating electrode or grid consists of a very thin metal disc 17 welded to and closing a circular hole 18 in a narrow supporting metal strip 19, which is laid flat on the upper face of the disc 13 so that the disc 17 faces away from the disc 13, and the strip 19 is fixed to the disc 13 by eyelets 20 in diametrically opposed holes provided in the disc and spaced at 90° to the holes receiving the cathode fixing eyelets 16. The disc 17 constitutes the grid proper and has a circular hole 21 therein coaxial with the cathode tube 11 and the hole 18 in the supporting strip 19. The latter hole 18 is made slightly larger than the diameter of the cathode in order to provide an insulating margin between cathode and grid. The insulation can be improved, if desired, by chamfering the edge of the top end 2 of the cathode tube and likewise the edge of the hole 18 which faces the cathode. A further precaution, if desired, is to coat the disc 13 with a suitable material such as magnesium oxide.

The grid supporting strip 19 thus serves at the same time as a spacer to maintain the correct grid-cathode clearance. The thickness of the strip 19 is within close limits made identical with the grid-cathode clearance desired. The choice of this clearance depends upon the desired operating characteristic of the cathode ray tube in which the structure is employed, and is a very important design parameter. In modern cathode ray tubes the range covered is approximately from .1 to .5 mm. The thickness of the supporting strip 19 may, therefore, be anything between .1 and .5 mm., but usually a maximum thickness of .2 to .3 mm. only can be allowed in order to provide a strong enough field at the cathode.

The diameter of the hole 21 in the grid disc 17 and its thickness are chosen in accordance with the requirements for the spot size or definition desired, the beam current, the length of the grid base, and the beam current cut-off point. The diameter of the hole 21 may therefore, in practice, vary between .1 and 1.2 mm. and the thickness of the grid proper between .025 and .20 mm. By way of illustration, three sets of values which have been used in actual tube constructions are:

	Hole diameter	Thickness of grid
	Mm.	*Mm.*
1	.15	.030
2	.40	.060
3	.80	.10

The cathode-grid clearance and the grid-anode clearance have, of course, to be taken into account when the other parameters are chosen to fulfil a set of desired operating conditions.

Since the coated end 12 of the cathode is flush with the upper face of the disc 13, the grid supporting strip 19 is flat on the upper face of the disc 13 and the grid proper 17 is flat on the upper face of the strip 19, all of which parts are assembled together in invariable relation on the disc 13 as main support and carrier for the assembly, it will be appreciated that the described structure ensures in a simple manner the maintenance of the clearance between cathode and grid at the pre-set value and provides a compact and sturdy structure.

To prevent spurious discharges and the deposition of nickel from the cathode on to the disc 13, which might impair the good insulation of the electrodes fixed to that disc, a cathode shield 22 is provided surrounding the cathode and part of its heater and abutting against the underface of the disc 13. This cathode shield may be in the form of a metal cylinder 22 which may be fixed to the assembly by welding it at its upper end to the cathode fixing eyelets 16 in any convenient manner, such as by welding the cylinder to short pieces or brackets of stiff wire which are welded in turn to the eyelets. The upper edge of the cylinder is notched or recessed at 23 adjacent the eyelets 20 so as to provide sufficient insulating margin between them. Welded to the inside of the cylinder 22 are a pair of inclined side shields or plates 24 which are disposed so as to protect the disc 13 from cathodic deposition in the neighborhood of the eyelets 20. Aligned inspection holes 25, 26 are provided in the periphery of the cylinder 22 and in one side shield 24 respectively. The shielding cylinder 22 is closed at its lower end by a metal thimble 27 welded to the cylinder, the thimble having an aperture 28 therein for passage of the cathode heater leads 29.

Sometimes only one high potential anode is employed which may consist of a conducting deposit on the glass wall of the cathode ray tube envelope. In other cases, one or more additional anodes are used. In these cases, the first anode is also included in the structure mounted on the disc 13. In the embodiment shown in Fig. 1, the first anode is in the form of a flanged-rim metal cup 30 of say .2 mm. thick material having a centre hole 31 in its bottom, which is mounted coaxially on the disc 13 by means of a metal claw ring 32 which surrounds the cup 30 with the interposition of a metal packing ring 33, of stouter material than the anode cup, e. g., .5 mm. thick material, the packing ring 33 being welded to the anode cup 30 and the claw ring 32 being welded to the packing ring 33. The claws 34 of ring 32 embrace the periphery of the insulating disc 13 and fix the anode cup 30 to the disc with the required spacing between anode and grid. The anode 30 is thus rigidly assembled with the rest of the structure on the disc 13, and the grid-anode spacing is kept at a constant value by reason of the rigidity of the assembly.

The whole structure is supported on the stem 10 by means of stiff wire leads welded to the electrodes. The two wires 35 (which provide cathode leads) are welded to the closure thimble 27 of the cathode shield 22, the anode lead 36 is welded to the claw ring 32, and the grid lead 37 is welded to a tag 38 formed integrally at one end of the grid supporting strip 19.

The electrode assembly of Fig. 1 has specifically been applied to a two-anode cathode ray tube with magnetic deflection and focussing, the second anode being formed in conventional manner by a conductive coating on the glass wall of the tube.

The structure illustrated in Figs. 2 and 3 is similar to that of Fig. 1 in essentials as regards assembly, location and spacing of the electrodes mounted on the insulating disc 13, but distinguishes from it in some particulars. The structure is mounted on a cup-shaped moulded glass base 39 instead of a stem or pinch. The glass base 39 has lead-in pins 40 sealed therethrough and arranged in a circle near the periphery of the bottom of the cup-shaped base. This type of mounting enables the leads to be kept short and widely spaced, thus making full use of the reduced grid capacity achieved by the described electrode construction and assembly on the disc 13. The use of a moulded glass base makes the assembly even more compact as contrasted with that of Fig. 1.

The cathode shield 41 is, in Figs. 2 and 3, shown as being of rectangular, box-like form instead of the cylindrical form of the shield in Fig. 1, the bottom of the shield 41 being, however, closed in similar fashion by a rectangular closure plate 42 welded on and having an aperture therein allowing the heater leads 29 to pass through. The shield 41 does not, in this case, enclose the underside of the eyelets 20 which fasten the grid supporting strip to the disc 13, in consequence of which no side shields as provided in the cylindrical shield are required. As a further consequence, the grid lead 37 may, in this case, be welded directly to one of the eyelets 20, as is shown in Figs. 2 and 3, and the previously described tag on the grid supporting strip omitted. Of course, the connection of the grid lead to the strip may alternatively be made in the manner previously described with reference to Fig. 1.

Also, the anode cup and packing ring are differently proportioned compared with those parts in Fig. 1. The anode cup 30*a* is shallower and with a flangeless rim, and the packing ring 33*a* extends substantially above the rim of the anode cup. Another difference from the structure of Fig. 1 appears in the use of an insulating spacer 43 between the grid and anode. This spacer is a strip of suitable material such as mica fixed by an eyelet 44 in one end to a support wire 45 welded to the eyelet 44 and to the cathode shield 41, the strip 43 extending between the insulating disc 13 and anode 30*a* so as to overlie the grid disc proper, the thickness of the strip 43 being made that of the clearance between grid and anode. The portion of the strip 43 lying over the grid disc has a hole therein aligned with the grid and anode holes but larger than them. The provision of such an insulating spacer as strip 43 adds more parts and assembly operations to the construction and also introduces increased capacity. On this account the use of such a spacer is restricted to cases where the grid disc has to be extremely thin such as .03 mm. thick. The purpose of the spacer in this case is to keep the very thin grid disc from buckling and so changing the clearances and the plane-parallelity of the electrode surfaces.

Fig. 6 illustrates an application of the cathode-grid-anode assembly structure according to this invention to a three-anode cathode ray tube with electrostatic focussing. The construction of Fig. 6 is similar to that of Fig. 1 as regards the cathode, grid and first anode assembly and illustrates how additional electrodes may be included in the assembly in proper and constant location and spacing. In this case, contrasted with the structure of Fig. 1, in assembling the closing thimble 27 to the cathode shield cylinder 22, a centering star ring 46 of mica or another suitable insulator is secured to the cylinder 22 by its inner periphery being held between the lower edge of the cylinder and the adjacent flange of the thimble 27, the extremities of the ring 46 engaging the internal surface of the glass wall 47 of the neck of the cathode ray tube. The ring 46 has an eyelet 48 in a hole therein for passage therethrough of the lead 36 for the first anode 30, and is also provided at suitable angular spacings with eyelets 49 through which pass the lower ends of a suitable number, for instance three, of stiff support wires 50 for the second or focussing anode 51. Also, in assembling the first anode 30 to the disc 13, another mica ring 52 is secured to the first anode 30 by being held at its inner periphery between the upper edge of the packing ring 33 and the flanged rim of the anode cup, and this ring 52 is provided with eyelets 53 through which the support wires 50 pass. The lower part of the second anode 51 is fitted with a mica ring 54 similar to ring 52 and in like manner furnished with eyelets 55, and another centering star ring 56 with eyelets 57 is fitted on the upper part of the second anode 51. The wires 50 pass through the eyelets 55 and 57, and are suitably secured as by welding to such of the eyelets as are necessary to afford a rigid location and spacing of the electrode 51. One of the support wires 50 serves as a lead to the second anode 51 through connecting wire or strip 58. The third anode is the usual conductive coating 59 deposited on the glass wall 47.

The location and spacing of the anode 30 with reference to the grid 17 may be effected in an alternative manner as illustrated in Figs. 7 and 8 by employing a modified form 13*a* of the insulating supporting disc which is formed with suitably shaped bosses 60 which provides seatings for the anode 30 and act as spacers to maintain the anode at the required distance from the grid disc 17. The anode 30, in this case, may be directly secured to the disc 13*a* by eyelets 61 in holes 62 through the bosses 60. The cathode fixing eyelets 16 are in holes 63 which, in this case, are countersunk in the bosses 60 so as to afford a sufficient insulating margin between the heads of the eyelets 16 and the bottom of the anode cup 30 seating on the bosses 60. At the same time these bosses 60 may be shaped so as to locate between them the grid supporting strip 19 which lies flat on the plane recessed surface 64 of the disc 13*a* between the bosses, so that in this way the bosses also ensure a proper centering of the grid hole 21. In view of the provision of anode fixing holes and eyelets in the disc 13*a*, a further slight modification is also made in this case contrasted with Fig. 4 in displacing the position of the cathode fixing holes and eyelets so as to obtain a wider and better spacing of the eyelet holes in the disc 13*a*.

In the cathode-grid-anode assembly described, the electrode surfaces are plane-parallel, but the invention does not depend upon and is therefore not limited to this type of design, since other shapes may be employed. The upper face of the grid disc proper may, for example, be shaped to form a spherical surface as indicated at 17*a* in Fig. 9, or a conical surface as indicated at 17*b* in Fig. 10, or in another alternative the grid disc may be attached to a short cylinder forming a cup-shaped grid as illustrated at 17*c* in Fig. 11. Also, the cathode need not always have a flat top end as previously described but may be suitably curved as, for instance, in a concave form as il-

lustrated at 12a in Fig. 9. Further, the bottom of the anode 30 facing the grid may be tapered or shaped in a way such as to reduce the grid-anode capacity to a minimum. An advantage of forms of grid plate such as are represented by 17a and 17b in which the thickness of the plate decreases from its periphery to the hole therein, is that the accelerating field between the grid and the anode reduces in many cases the spread of the emerging electron beam, and that the grid can be made extremely thin at the hole to suit the spot size or definition required while it may be made thicker elsewhere so as to render it relatively stout and able to withstand buckling.

The shape of the grid supporting strip 19 as shown in the drawings is the preferred shape as an optimum compromise between maximum mechanical strength and minimum interelectrode capacity. However, other shapes are not excluded and the strip may, for instance, be straight-edged.

While a number of specific embodiments of the invention have been shown and described and certain modifications therein have been particularly pointed out in this specification, it is to be understood that various other modifications and changes may be made without departing from the invention, the scope of which is limited only by the appended claims.

I claim:

1. In a cathode ray tube, an electrode structure comprising an insulating support having an aperture in a surface thereof, a cathode secured to said support in said aperture so that an electron emissive surface of the cathode is fixed with respect to said disc surface, a narrow metal strip secured to said support and lying on said surface thereof with a hole in said strip in line with said cathode surface, and a modulating electrode lying on and conductively secured to said strip and closing said hole therein with a hole in said electrode in line with said cathode surface, the thickness of said strip determining the spacing between said modulating electrode and said cathode.

2. In a cathode ray tube, an electrode structure comprising a disc of insulation having an aperture in a flat surface thereof, a cathode rigidly secured to said disc in said aperture and having an electron emissive surface flush with said disc surface, a flat narrow metal strip secured on said disc surface and having a hole therethrough which is in line with and larger than said cathode surface, and a modulating electrode having a flat portion with a hole therein conductively secured to said strip with said flat portion closing the hole in said strip and the hole in said flat portion in line with said cathode surface, said cathode surface and said flat portion of said modulating electrode being spaced by the thickness of said strip.

3. An electrode structure as defined in claim 2, wherein said modulating electrode is directly welded by its said flat portion to said strip.

4. An electrode structure as defined in claim 2, wherein said modulating electrode comprises a thin metal disc having a flat face, and is welded by its said face to said strip.

5. A modulating electrode assembly for a cathode ray tube, comprising a flat narrow metal spacer strip having a relatively large hole therethrough intermediate its ends, and a very thin metal disc constituting the modulating electrode proper having a flat face welded to one face of said strip so as to close said hole therein, said disc having a fine hole therethrough coaxial with said hole in said strip, said strip having an eyelet fixing hole therethrough near each of its ends.

6. A modulating electrode assembly as defined in claim 5, wherein the portions of said strip between each fixing hole and the hole closed by said disc are of reduced width.

7. In a cathode ray tube, an electrode structure comprising a disc of insulation having a hole therethrough, a tubular cathode member secured to said disc in said hole and having a closed end provided with an electron emissive surface arranged flush with a flat surface of said disc, said tubular member projecting from the opposite face of said disc, a narrow metal strip secured to said disc and extending flat on said flat disc surface across said hole therein, said strip having a hole therethrough which is in line with but larger than said cathode surface, a modulating electrode fixed on said strip and closing said hole therein, with a hole in said electrode in line with said cathode surface, said strip supporting and spacing said electrode from said cathode, and a tubular metallic shield secured to said opposite face of said disc and surrounding the cathode tube projecting from said face.

8. In a cathode ray tube, an electrode structure comprising an insulating support having an aperture in a surface thereof, a cathode secured to said support in said aperture so that an electron emissive surface of the cathode is fixed with respect to said disc surface, a narrow metal strip secured to said support and lying on said surface thereof with a hole in said strip in line with said cathode surface, and a modulating electrode lying on and conductively secured to said strip and closing said hole therein with a hole in said electrode in line with said cathode surface, the thickness of said strip determining the spacing between said modulating electrode and said cathode, an anode having a hole therein in line with the hole in said modulating electrode, and means securing said anode to said insulating support in parallel spaced relation to said modulating electrode.

9. In a cathode ray tube, an electrode structure comprising a disc of insulation having an aperture in a flat surface thereof, a cathode secured to said disc within said aperture and having an electron emissive portion flush with said surface, a narrow flat metal strip secured to said disc and extending flat on said surface across said aperture, said strip having a hole therethrough in line with and larger than said cathode portion, a modulating electrode comprising a plate fixed flat on said strip and closing the hole therein, with a hole in said plate in line with said cathode portion, said strip spacing said plate from said cathode, an anode having a surface facing and parallel to said plate, with a hole in said anode surface in line with the hole in said plate, and means including a plurality of claws secured to said anode which embrace and grip the periphery of said disc to fix and support said anode on said disc in spaced relation to said plate.

10. In a cathode ray tube, an electrode structure comprising a disc of insulation having an aperture in a flat surface thereof, a cathode secured to said disc within said aperture and having an electron emissive portion flush with said surface, a narrow flat metal strip secured to said disc and extending flat on said surface across said aperture, said strip having a hole therethrough in line with and larger than said cathode portion, a modulating electrode comprising a plate fixed flat on said strip and closing the hole

therein, with a hole in said plate in line with said cathode portion, said strip spacing said plate from said cathode, a plurality of spacer bosses upstanding from said flat surface of said disc at opposite sides of said strip, an anode seated on said bosses and spaced thereby from said plate, with a hole in said anode in line with the hole in said plate, and means securing said anode to said disc.

11. In a cathode ray tube, an electrode structure comprising a disc of insulation having a hole therethrough, a tubular cathode member secured to said disc in said hole and having a closed end provided with an electron emissive surface arranged flush with a flat surface of said disc, said tubular member projecting from the opposite face of said disc, a narrow metal strip secured to said disc and extending flat on said flat disc surface across said hole therein, said strip having a hole therethrough which is in line with but larger than said cathode surface, a modulating electrode fixed on said strip and closing said hole therein, with a hole in said electrode in line with said cathode surface, said strip supporting and spacing said electrode from said cathode, a tubular metallic shield secured to said opposite face of said disc and surrounding the cathode tube projecting from said face, an anode having a hole therein in line with the hole in said modulating electrode, and means securing said anode to said disc in parallel spaced relation to said modulating electrode.

12. An electrode structure as defined in claim 11, and including an insulating ring around and secured to said tubular shield, a second insulating ring around and secured to said anode, each of said rings having a set of angularly spaced holes therethrough in line with the holes in the other ring, parallel rigid support rods extending through aligned holes in said rings beyond said anode, a tubular electrode disposed between said rods beyond said anode, and means securing said tubular electrode to said rods in coaxial spaced relation to said anode.

13. An electrode structure as defined in claim 8, and including an insulating spacer between said anode and modulating electrode.

14. In a cathode ray tube, an electrode structure comprising a disc of insulation having an aperture in a flat surface thereof, a cathode secured to said disc within said aperture and having an electron emissive portion flush with said surface, a narrow flat metal strip secured to said disc and extending flat on said surface across said aperture, said strip having a hole therethrough in line with and larger than said cathode portion, a modulating electrode comprising a plate fixed flat on said strip and closing the hole therein, with a hole in said plate in line with said cathode portion, said strip spacing said plate from said cathode, an anode having a flat surface facing and parallel to said plate, with a hole in said anode surface in line with the hole in said plate, a narrow insulating spacer strip extending from the periphery of said disc between the opposed faces of said plate and said anode, said spacer strip having a hole therein in line with the holes in said plate and anode and larger than said holes, means securing said anode to said disc, and means securing said insulating strip by its outer end to the structure.

15. In a cathode ray tube an electrode structure comprising a disc of insulation having an aperture in a flat surface thereof, a cathode secured to said disc within said aperture and having an electron emissive portion flush with said surface, a narrow flat metal strip secured to said disc and extending flat on said surface across said aperture, said strip having a hole therethrough in line with and larger than said cathode portion, a modulating electrode comprising a metal disc having a flat surface and fixed with its said flat surface flat on said strip and closing the hole therein so that said strip spaces said disc from said cathode portion, said disc having a small hole therethrough in line with said cathode portion and said disc tapering in thickness radially from its outer periphery to its hole.

16. In a cathode ray tube, an electrode structure comprising a disc of insulating material having a flat surface with a centre hole therein, a cathode secured in said hole in said disc and having a disc-shaped electron emissive surface in the plane of said disc surface, a modulating electrode comprising a narrow plane-parallel metal supporting strip having a hole therethrough larger than said cathode surface and secured to said disc with one face of the strip contacting said flat surface of said disc and with the hole in said strip coaxial with said cathode surface, and a metal disc constituting the modulating electrode proper secured flat on the other face of said strip and closing the hole therein, with a centre hole in said metal disc coaxial with said cathode surface, said metal disc lying parallel to said cathode surface and is separated therefrom by a spacing determined by the thickness of said strip on which said metal disc is mounted, and a cup-shaped anode supported by said insulating disc over said metal disc with its open end facing away from said discs and having a flat disc-shaped bottom surface with a centre hole therein positioned parallel to and coaxial with said cathode surface and said metal disc.

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