Dec. 6, 1955 R. E. BENWAY 2,726,348

MULTIPLE BEAM GUN

Filed May 26, 1953 2 Sheets-Sheet 1

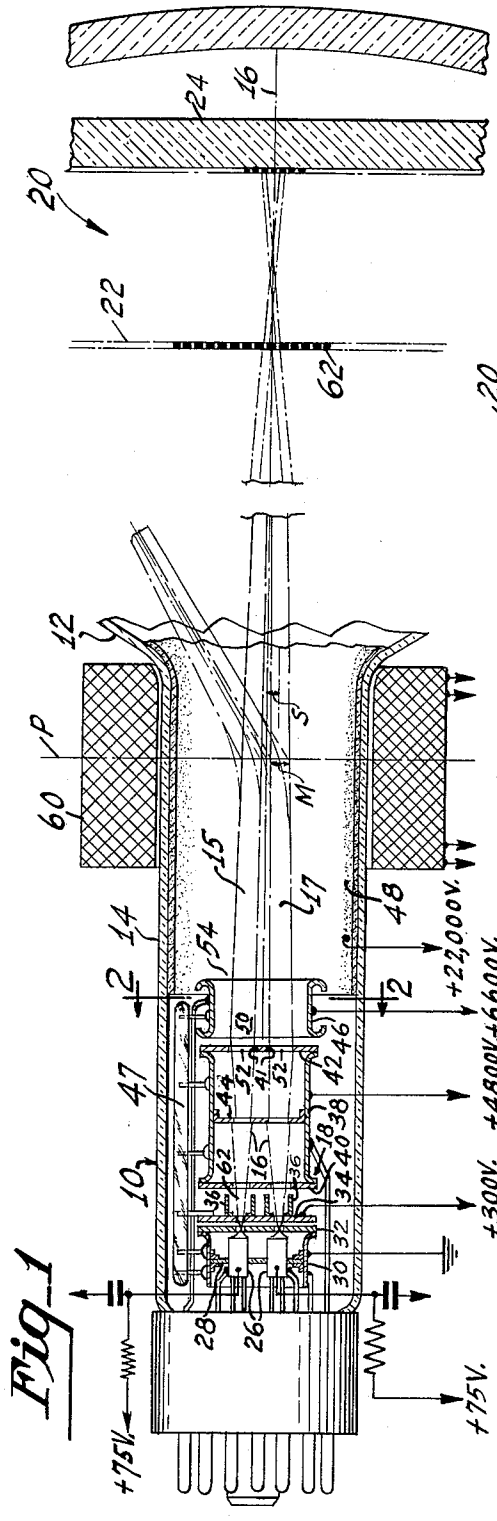


Fig. 1

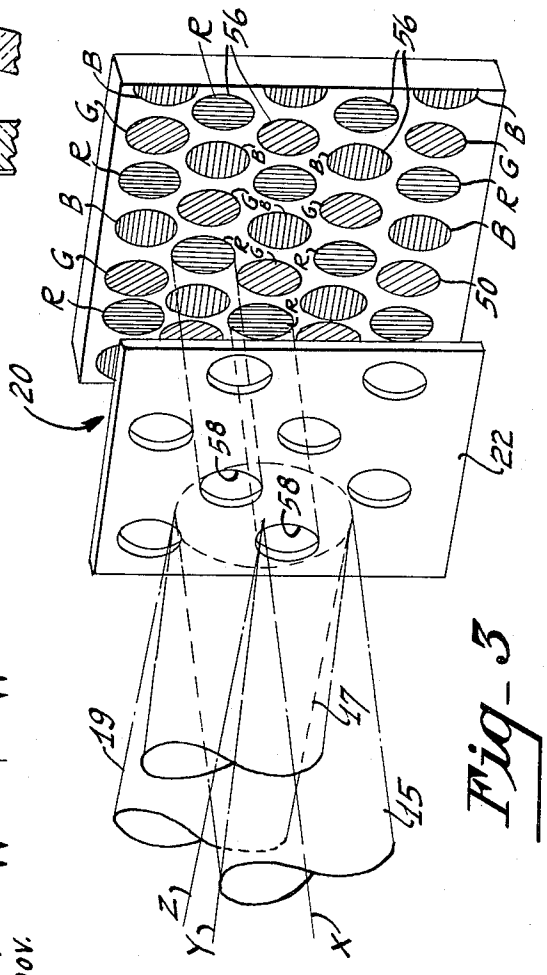


Fig. 3

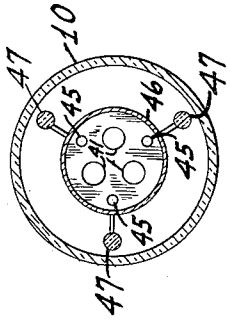


Fig. 2

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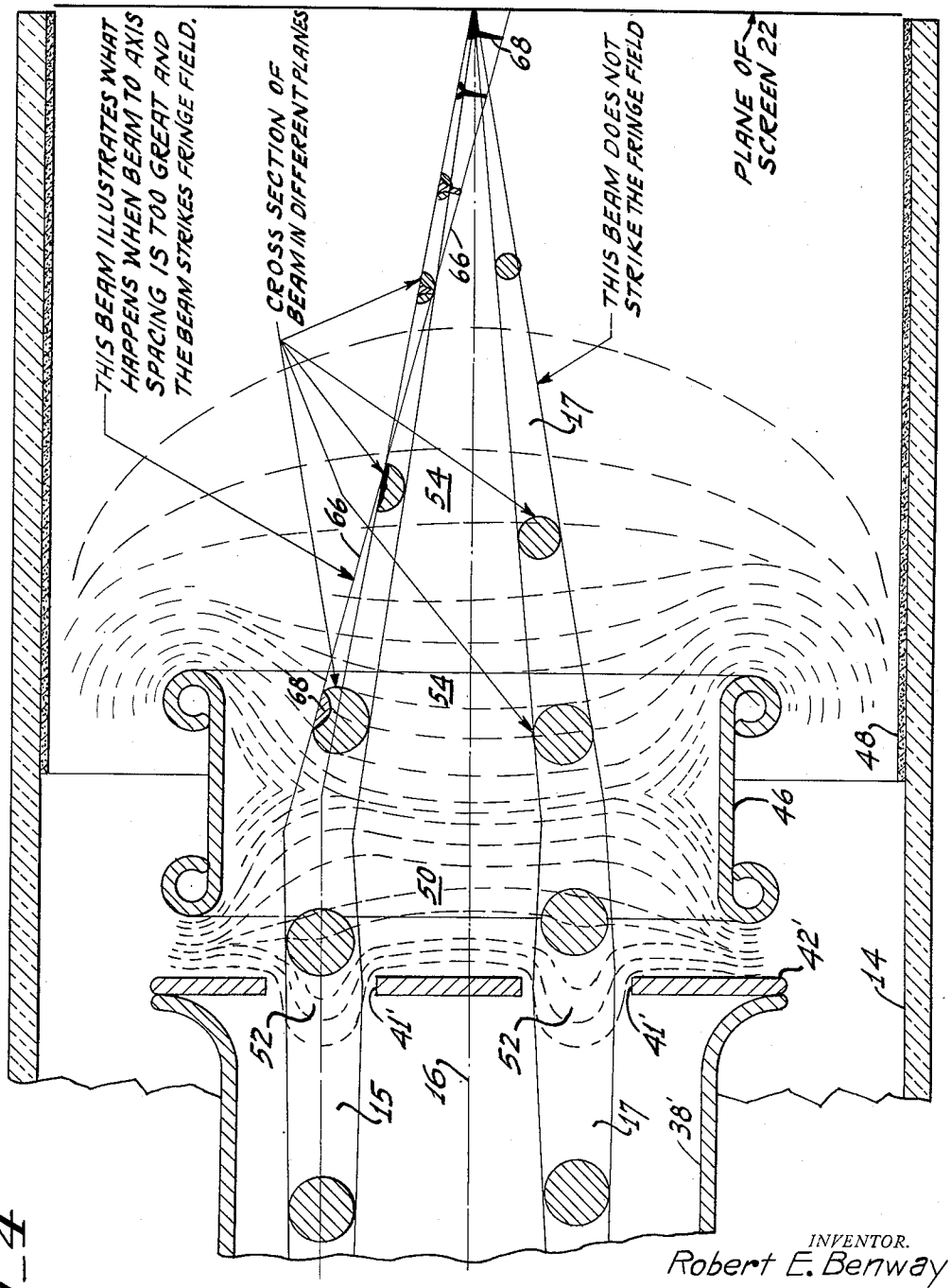


Fig_4

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MULTIPLE BEAM GUN

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Application May 26, 1953, Serial No. 357,511

5 Claims. (Cl. 313—70)

This invention is directed to electron discharge devices of the cathode ray tube type and more specifically to cathode ray tubes used as viewing tubes for color television.

One type of cathode ray viewing tube for color television, disclosed in the copending application of Hannah C. Moodey, Serial Number 295,225, filed June 24, 1952, utilizes three electron guns for forming three parallel electron beams arranged symmetrically about the tube axis and directed at a target electrode within the tube envelope. A combined converging and focusing lens, formed by potential differences between three electrodes, is used to converge the three electron beams to a common point on the target.

The target electrode consists principally of a masking electrode formed of a thin metal sheet having a large number of small apertures formed therethrough. The apertured masking electrode is mounted substantially normal to the tube axis and in the paths of the electron beams. Conventional scanning coils are used to scan the three beams simultaneously over the apertured mask electrode in a rectangular raster. A glass target support plate is mounted close and parallel to the side of the masking electrode opposite to the electron guns.

There is formed, on the glass support plate, groups of phosphor dots with each group consisting of three dots spaced 120° from a common point, which in turn is aligned with one of the apertures through the masking electrode, so that there is one group of phosphor dots aligned with each aperture of the masking electrode. The three phosphor dots of each group are formed respectively of phosphors luminescing in different colors as red, green, and blue.

Since the three parallel beams of the color tube are converged to a common point on the masking electrode, the electrons of each beam strike the masking electrode from substantially three different directions. The beams are scanned simultaneously by conventional scanning coils over the masking electrode surface. The electrons from the three beams will pass through the apertures of the masking electrode along paths which are respectively extensions of the directions from which the beams strike the masking electrode, and will strike separate phosphor dots of each group. This arrangement results in the electrons then of each beam striking phosphor dots which luminesce with one color.

A tube of the type described above can be utilized with various types of color systems in which the color signals are either formed and transmitted simultaneously or in a sequential order and in which each signal may comprise an elemental signal or a frame signal. The signals are applied each independently to the three guns of the viewing tube so that the three electron beams are independently modulated to provide the color response at the correct time interval.

In tubes of the type described, the three electron beams are directed along paths toward the target electrode. The

electron paths are spaced from each other and positioned symmetrically about a common axis. The electron lens fields, through which the beams pass, have their greatest uniformity at their centers. Furthermore, the scanning coils are coaxially mounted about the common axis of the electron beams so that the beams will pass into the deflecting fields substantially at the center of the fields. The three beams are deflected simultaneously from the tube axis and at the time of greatest deflection will pass through fringing portions of the deflecting fields, which are less uniform than the central portions of the fields. If the beams are widely spaced from each other, the fringing portions of the deflecting fields will cause deflection distortion due to the deflecting fields acting differently on each beam. However, it is desirable that the deflection of the three beams together be identical or substantially uniform. Deflection distortion results in a misconvergence of the three beams at the target and the beams strike the target at separated spots. Misconvergence of the beams on the target is in direct relationship to the beam spacing in the yoke.

Because of deflection distortion which results in misconvergence of the beams of the target, as described above, the converging lens for bringing the three beams to a point of convergence at the screen must be varied in accordance with the amount of deflection of the three beams. That is, a varying voltage is applied between the electrodes forming the converging lens to modulate the convergence of the three beams in accordance with the deflection of the beams, to provide beam convergence at all angles of beam deflection. This modulating voltage is known as the dynamic voltage and varies in value up to 3,000 volts in tubes of the type described.

Convergence of the three beams of the target is also directly related to the alignment of the gun parts forming the electron beams as well as the symmetry of the beam paths about a common axis. If gun parts are misaligned or are unsymmetrically positioned in the tube, the converging and deflecting fields acting simultaneously on the beams will have different actions on the beams such that there will be a lack of convergence of the beams at the target.

It is, therefore, an object of this invention to provide a color picture tube of improved design.

It is another object of this invention to provide a color picture tube having a minimum of deflection distortion.

It is also an object of this invention to provide a color picture tube having a reduced dynamic convergence voltage requirement.

It is also an object of this invention to provide a color picture tube having improved gun alignment in order to reduce beam distortion and to improve picture resolution.

The invention is specifically related to a color picture or viewing tube having a masking electrode at the target whereby electrons approaching the target from one of several directions will strike phosphor portions of the target luminescing with a single color of light. To reduce the deflection distortion as well as the dynamic convergence voltage requirements of the tube, the electrodes forming the converging lens of the tube are designed to provide a minimum of beam distortion. Also the gun is assembled with an improved alignment technique so that the electron beams can be spaced closer together to minimize deflection distortion as well as beam spot distortion at the target.

Figure 1 is a sectional view of portions of a color picture tube in accordance with the invention.

Figure 2 is a sectional view along line 2—2 of Figure 1.

Figure 3 is a schematic representation of a target portion of the picture tube of Figure 1.

Figure 4 is a schematic representation of the shape and action of the focusing and converging fields of a tube similar to that shown in Figure 1.

Figure 1 shows a color television picture tube consisting of an evacuated envelope **10** having an enlarged bulb or shell portion **12** fixed to a tubular neck portion **14**. The tubular neck **14** and the bulb portion **12** are axially aligned along a common axis **16**. Mounted at one end of the neck portion is an electron gun means **18** for providing a plurality of electron beams **15**, **17** and **19** along paths which are symmetrically spaced from the axis **16**. Mounted substantially normal to the axis **16** of the tube and within the opposite end of the bulb portion **12** is a target electrode assembly **20** consisting of a thin metallic sheet **22** tightly stretched in a closely spaced parallel relationship to a glass support sheet **24**. Details of the target construction and mounting are not given here but may be of the type disclosed, for example, as U. S. Patent 2,611,100 of R. D. Faulkner et al.

The electron gun **18** consists of a plurality of electron sources consisting of cathode electrodes **26**, each of which are formed of short tubular members mounted axially parallel in a ceramic insulating spacer **28**, which is in turn fixed within the short tubular control electrode **30** coaxially mounted within the neck portion **14**. The cathode electrodes **26** are closed at the end facing the target **20** and are coated with thermionic emitting material (not shown) for providing sources of electrons.

The control electrode **30** is closed at the end facing the target **20** by a plate member **32** having a plurality of apertures therethrough, with one aperture aligned with each coated end of the cathode electrodes **26**. Closely spaced along the axis **16** from the grid plate **32** is a first accelerating electrode plate **34** mounted in a parallel plane to that of plate **32**. Accelerating plate **34** is also apertured, with one aperture aligned with each of the apertures in plate **32**.

Spaced along the axis **16** is a second accelerating electrode **38** consisting of a tubular member closed at both ends by apertured plates **40** and **42**, respectively. Again, each aperture **41** in plate **42** is aligned with a corresponding aperture in plate **40** and with an aligned pair of apertures in plates **32** and **34** to provide a straight line path for the passage of electrons from the respective cathode electrodes **26** through the accelerating electrode **38**.

Mounted within the tubular accelerating electrode **38** is a beam masking diaphragm or plate member **44**, also having a plurality of apertures with one aperture aligned with each of the straight line paths from cathodes **26** through the tubular electrode **38**.

Spaced along the axis **16** and mounted coaxially thereto is a third accelerating electrode **46** consisting of a short tubular member enclosing the straight line paths from the cathodes **26** to the screen **20**. A fourth accelerating electrode is formed as a conductive coating **48** on the inner surface of the tubular envelope portion **14** and also encloses all of the straight line paths from the several cathode electrodes **26** to the screen **20**.

The operation of the electron gun **18** is that in which appropriate voltages are applied to the several electrodes as indicated in Figure 1. These voltage values are in no way limiting but represent typical voltages which have been used to operate tubes of this type. Within each cathode electrode **26** is mounted a heater filament (not shown), which, during tube operation, raises the cathode emissive material to a thermionic temperature.

The electrons emitted from each cathode pass through the aligned apertures in plates **32** and **34**. The configuration of the electrostatic field formed between plates **32** and **34**, at operating potentials, causes the electrons from each cathode to form a beam having a

minimum cross sectional area or "crossover point" near plate **34**. From each crossover point **33** the electrons pass respectively into the tubular electrode **38** as diverging beams. The fringe portions of each beam are masked off or collected by the corresponding apertures of plate **44**. The apertures **41** in plate **42** are sufficiently large that the central portions of each beam, passing through the respective aperture of plate **44**, do not strike the edges of these apertures in plate **42**.

Due to the differences of potential between electrodes **38** and **46** there is formed an electron lens field **50** therebetween and as schematically shown in Figure 4. One portion of the lens field **50** extends through the apertures **41** in accelerating electrode plate **42** to form separate fields **52**, with one field **52** in the path of each electron beam. The fields **52** have a curvature of a degree that changes the individual electron beam from divergence to convergence. The converging action of fields **52** focuses each beam to a small spot on the masking electrode **22** of target **20**. Fields **52** constitute the main or principal focusing field for each electron beam, respectively.

Between the third accelerating electrode **46** and the accelerating electrode coating **48**, there is also established an electron lens field **54** having somewhat the configuration schematically shown in Figure 4. All of the beams pass through the common field **54** and the nature of the field is to provide convergence of each beam toward the field axis which is common with axis **16** of the gun and tube. Field **54** is adjusted to bring the several beams to a common point of convergence on the axis **16** and at the target masking screen **22**. The common converging field **54** also adds somewhat to the focusing of the electrons in each beam to a minimum spot on the masking electrode **22** of the target. The operation of the gun **18**, as described above is similar to that described in the above cited copending application of Hannah C. Moodey.

On the surface of the glass support plate **24** of target **20**, there is formed a large number of phosphor dots **56** and as shown more specifically in the enlarged sketch of Figure 3. The phosphor dots **56** are arranged in groups of three, with the dots in each group spaced 120° about a common center point. Each dot in every group is formed of a different fluorescing phosphor material and, as indicated in Figure 3, the phosphor materials will luminesce with red, green, or blue light, respectively, when struck by high energy electrons.

As shown in Figure 3, the screen structure is such that the alignment of each separate phosphor dot with its respective aperture **58** is along a directional line X, Y, or Z, each of which forms a small angle with the line joining the center of the aperture **58**, with the center of the respective group of phosphor dots. Electrons passing through each aperture **58** of Figure 3, along each one of the directional lines X, Y, or Z will strike only one of the phosphor dots. For the purpose of clarity the portions of the Z and Y beams that project through apertures **58** and hit phosphor dots **56** are not shown. The three electron beams **15**, **17** and **19** upon converging to a common spot on the masking screen **22** will pass through whatever apertures **58** are covered by the beam spot. Thus, from Figure 3 it can be seen that all of the electrons from one beam passing through electrode **22** will only strike those phosphor spots which fluoresce with the same color and the screen **22** will mask the electrons of each beam from all of the other phosphor spots fluorescing with the other colors.

Means are provided for scanning the three beams of Figures 1 and 3 over the surface of the target **20**. The deflecting means are shown schematically as a yoke structure **60** mounted on the tubular envelope portion **14**. The yoke **60** is of a conventional design and operation and is constituted principally of two pairs of coils, with the coils of each pair connected in series with each other to a source of saw tooth currents for providing line and

frame scansion of the electron beams over the surface of target **20**. The operation of the tube described is also disclosed in greater detail in the above cited copending application of Hannah C. Moodey.

The deflecting fields of yoke **60** act simultaneously on the three beams to scan the beams over the target in a normal rectangular raster. Figure 1 schematically shows the paths of the beams during one point of their deflection. The problem of scanning three spaced beams simultaneously is different than that in scanning a single beam from the axis of the deflection yoke. When the beams are deflected by the fields of yoke **60**, they are directed off the axis **16** into the fringing portions of the deflecting fields. Since the beams are spaced from each other and the distance from one beam to the other is of a significant amount, the beams at the same moment pass through different non-uniform portions of the deflecting field and will thus be deflected by different amounts at the edges of the rectangular raster. Because of this non-uniformity of the deflecting fields in the fringe areas the three beams converge at three different spots, which are separated at the edge portions of the raster. Furthermore, it has been found that the separation of the three spots is in direct relationship to the separation of the beams in the yoke **60**. To counteract this deflection distortion or beam separation at the target, and to bring the beams to common convergence at all points of the scanned raster, it has been found necessary to modulate the voltage of electrode **46** in accordance with the deflection of the beams. This modulating or dynamic convergence voltage, which is required, amounts to a maximum of 3,000 volts in some tubes of the type described. Close spacing of the beams in the deflection yoke **60** would be an advantage in lowering the dynamic convergence voltage requirements.

It would appear that to provide closer spacing of the beams along the axis **16**, it would be merely a question of making the gun parts **18** smaller and of using smaller spacing between the aligned apertures of the gun which define the several beam paths. However, it has been found that the cup electrodes **36** limit the closeness to which the apertures in plate **34** can be positioned, for example. Furthermore, it has also been found that if the apertures **41** of plate **42** are too closely spaced, the focusing fields **52** will interfere with each other and cause distortion of the spot of each electron beam at the target.

In addition to deflection distortion described above, any misalignment or distortion of gun parts may prevent accurate convergence. To provide better aperture alignment, these electrode plates **32**, **34**, **40**, **44**, and **42** are each formed with an additional three alignment apertures **45** as shown in Figure 2, in plate **42**, for example. The gun parts then can be assembled with a mandrel having three rods, each rod being threaded through one aperture **45** in each of the electrode plates, together with appropriate spacers as is well known in the art. The mandrel rods are rigidly supported at both ends in accurate blocks and can be held to prevent possible twisting of the rods while the electrode portions of the gun are sealed into the glass mounting beads **47**. This method of assembling eliminates the use of the gun or beam apertures in each of the plates as alignment apertures and thus prevents their distortion, during gun assembly.

By thus utilizing a plurality of plates **32**, **34**, **40** and **42**, for example, which can be accurately aligned as described, it is not necessary to depend upon the tubular electrodes **30** and **38**, for example, for aperture alignment. Furthermore, the beam apertures in each of these electrode plates can be accurately punched so that the apertures are spaced accurately about a common center as shown in Figure 2, for example. With the improved alignment procedure, then, the common center of each plate can be mounted on the common tube axis **16**. Therefore, the electrons directed through the aligned apertures will be formed into beams accurately spaced, symmetrically, about the gun axis.

Figure 4 schematically discloses in detail the relationship of the converging and focusing fields **54** and **50**, respectively, with the spacing of the electron beams from the common axis **16**. Figure 4 is not identical with the structure of Figure 1 since the apertures **41'** in plate **42'** are not symmetrical to axis **16**. The upper half of Figure 4 actually represents a gun of different dimensions than the lower half. The prime numbers, however, indicate the relationship of parts to corresponding parts in Figure 1.

It has been found as described above that in using progressively smaller beam spacing in the gun, spot distortion will be produced at the screen. It has been found, on the other hand, that if the spacing of apertures **41'** from axis **16** is too great as shown in the upper portion of Figure 4, the electron beam **15** penetrates into the fringe area of fields **50** and **54**. The hatched sections, schematically shown along the beam path in the upper portion of Figure 4, substantially represents the cross sectional shape of the electron beam **15** at each corresponding point. It can be noted that as beam **15** emerges from the corresponding plate aperture **41'** it is focused by the converging portion of field **52** to provide a smaller and smaller cross sectional area, which becomes a minimum at the plane of screen **62**. Also beam **15** passing through aperture **41'** is first caused to diverge toward the fringe area of field **50** because of the curved nature of the field in that area. Beam **15** passes through this fringe area and enters the converging portion of field **54**. However, as shown in Figure 4, the upper portion of beam **15** passes through a more converging portion of field **54** so that the edge **68** of the beam is directed along a beam path **66**, for example. Thus, the beam cross sectional area begins to lose its uniformity as the more deflected portion **68** of the beam is deflected toward the center of the beam. As the beam moves toward the target, beam portion **68** follows path **66** and the distortion increases to an extent that instead of all portions of the beam striking the target at a small uniform spot, the beam strikes the target in a larger distorted spot.

The lower portion of Figure 4 discloses what substantially happens with an electron beam **17** which is more closely spaced to axis **16**. Beam **17** passes through aperture **41'** into a uniform portion of field **50** and is not first diverged away from the axis **16** into the fringe areas of the converging field **54**. Rather, beam **17** passes through the more central portions of fields **50** and **54**, which have interacted to form substantially uniform concentric potential surfaces to provide little or no distortion of the beam and also to provide a uniform convergence action on the beam. As shown in Figure 4, beam **17** passes into the converging portion of field **54** in an area where all portions of the beam are essentially uniformly refracted.

In accordance with the invention then, the design of the electron gun **18** is that in which the electron beams are not refracted by the fringe or distorting portions of fields **50** and **54**. The diameter, as well as, the length of the short tubular electrode **46** greatly determines the shape of the fields **50** and **54**. In Figure 4, it can be seen that as the length of electrode **46** becomes larger, field **54** is moved away from field **50** so that there is less interaction between the fields and each field assumes a greater curvature. This then moves the fringe or distorting portion of these fields closer to axis **16**. This has approximately the same effect as if each beam were moved away from the axis, as for example, from the position of beam in Figure 4 to the position of beam **15** of Figure 4.

Furthermore, it can be seen that, if the length of electrode **46** is gradually reduced, fields **50** and **54** will coact to a greater extent to eliminate the curvature of field **54** and thus reduce the convergence action of the field on the electron beams. Thus, there is an optimum re-

lationship between the spacing of the beam from axis 16 to the length of electrode 46, whereby optimum beam convergence will be provided. In tubes of the type described, it has been found that, with an electrode 46 having a diameter of ¾" an optimum length of electrode 46 is in the order of 0.400" with a beam spacing of 0.145" from axis 16. The beam may be moved away from axis 16 a distance of approximately .160" before there is any indication of spot distortion. Also, the length of electrode 46 may be 0.200" more or less than the above dimension without causing any significant spot distortion.

Thus, with a minimum length of electrode 46 equal to approximately 0.200" and a beam spacing from the axis 16 of 0.145", the ratio of the length of the electrode 46 to the spacing of the beam from axis 16 is in the order of 1.4. The value of this ratio can only be reduced by making the length of electrode 46 smaller or the spacing of the beam from axis 16 larger. Both of these conditions, however, would result in spot distortion so that the ratio value, 1.4, can be considered as a lower limit for optimum beam focus at the target. The value of this ratio may be increased by increasing the length of electrode 46 within the limits described or by decreasing the spacing of the beam from axis 16. However, the spacing of each beam from axis 16 is not only limited by physical conditions in the manufacture of the gun 18, but also from the fact that the focusing fields 52 will interact with each other if the spacing becomes too small.

The inside diameter of electrode 46 is also a controlling factor in the condition of electron gun design. If the diameter of electrode 46 is decreased, both fields 54 and 50 will assume a greater curvature with a resulting movement of the fringe areas toward the axis 16 and thus provides an effect similar to that produced by lengthening electrode 46. Increasing the diameter of electrode 46 has the opposite effect and reduces the convergence action of field 54 on the several beams, as fields 50 and 59 then interact over a larger area and the resultant field becomes flatter. In a similar manner, then, the diameter of electrode 46 is related to the beam-to-axis spacing. With the ¾" diameter described above, it has been found that there is a minimum ratio in the order of 4.7 between the electrode 46 diameter and the beam-to-axis spacing. Increasing the beam-to-axis spacing decreases the ratio value and results in beam distortion since the beam is moved into the fringe portions of fields 50 and 54. Also decreasing the diameter has a similar effect and also provides beam spot distortion. However, decreasing beam-to-axis spacing as well as increasing the diameter of electrode 46 are both in the direction for eliminating spot distortion since the fringe areas of fields 50 and 54 and the beam paths are moved away from each other. However, as described above, for a given length of electrode 46, there is also a limit to which the diameter of the electrode may be increased since the convergence action of field 54 is changed considerably with the increase in the diameter of electrode 46. The dimensions previously given in which the diameter of electrode 46 is substantially ¾" and the beam spacing is .145" are optimum values and together provide a ratio of 5.2, which is above the minimum value stated above of 4.7.

The variations in electrode dimensions discussed above are dependent upon the same voltages being present on the electrodes in every case. However, varying the voltage of electrode 46 and keeping the voltages of electrodes 48 and 38 constant will cause a greater change in beam convergence than in the beam focusing. The focusing fields 52 are almost entirely independent of voltage changes within a large range of change of the convergence field 54. For example, the focusing action of fields 52 is affected very little by change in the voltage of electrode 46 but the configuration of field 54 is considerably altered.

The results of moving the electron beams closer to axis 16 and eliminating fringe fields in the beam path has resulted in a smaller spacing of the beams from the axis in the deflection yoke 60, whereby there is less deflection distortion and more accurate convergence of the three beams over the entire target. This then results in a smaller dynamic convergence requirement and, in tubes of the type described, such voltage requirements have been reduced from 3,000 volts to that in the order of 200 volts with consequent circuit simplification.

The improvement of aperture alignment has resulted also in a more symmetrical arrangement of the beams about axis 16 whereby they pass through identical portions of the converging and deflecting fields. Control of the relationship of the length and diameter of electrode 46 to the spacing of the beam from the axis 16 has resulted in the elimination of fringe fields from the paths of the respective electron beams. This in turn has eliminated spot distortion of the beams at the target.

While certain specific embodiments have been illustrated and described, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. An electron discharge device comprising, electron gun means for providing a plurality of beams along respective paths in a common general direction and symmetrically spaced from a common axis, a target electrode mounted transversely to said beam paths, electrode means between said gun and target for providing an electron lens in the paths of said beams for converging said beams to a common point at said target, said electrode means including a pair of tubular electrodes coaxially mounted on said axis and enclosing said beam paths, the ratio of the diameter of said tubular electrode nearer said gun to the spacing of said beams from said axis having a minimum value of 4.7.

2. An electron discharge device comprising, electron gun means for providing a plurality of beams along respective paths in a common general direction and symmetrically spaced from a common axis, a target electrode mounted transversely to said beam paths, electrode means between said gun and target for providing an electron lens in the paths of said beams for converging said beams to a common point at said target, said electrode means including a pair of tubular electrodes enclosing said beam paths, said pair of electrodes coaxially mounted on and spaced along said axis, the ratio of the length of the tubular electrode of said pair nearer said gun to the spacing of said beams from said axis having a minimum value of 1.4.

3. An electron discharge device comprising, electron gun means for providing a plurality of beams along respective paths in a common general direction and symmetrically spaced from a common axis, a target electrode mounted transversely to said beam paths, electrode means between said gun and target for providing an electron lens in the paths of said beams for converging said beams to a common point at said target, said electrode means including a pair of tubular electrodes enclosing said beam paths, said pair of electrodes coaxially mounted on and spaced along said axis, the ratio of the length of the tubular electrode of said pair nearer said gun to the spacing of said beams from said axis having a minimum value of 1.4 and the ratio of the diameter of said nearer electrode to the spacing of said beams from said axis having a minimum value of 4.7.

4. An electron discharge device comprising, electron gun means for providing a plurality of beams along respective paths in a common general direction and symmetrically spaced from a common axis, a target electrode mounted transversely to said beam paths, electrode means between said gun and target for providing an electron lens in the paths of said beams for converging said beams to a common point at said target, said electron gun including a tubular electrode coaxially mounted on said axis and having a wall portion closing the end of said tubular electrode facing said target, said wall portion having a plurality of apertures therethrough with said apertures

symmetrically spaced from said axis and with one of said apertures in the path of each of said beams, said converging lens electrode means including a pair of tubular electrodes coaxially mounted and spaced along said axis from said electrode wall portion, the ratio of the length of the tubular electrode of said pair nearer said tubular electrode wall portion to the spacing of said apertures in said electrode wall portion from said axis having a minimum value of 1.4.

5. An electron discharge device comprising, electron gun means for providing a plurality of beams along respective paths in a common general direction and symmetrically spaced from a common axis, a target electrode mounted transversely to said beam paths, electrode means between said gun and target for providing an electron lens in the paths of said beams for converging said beams to a common point at said target, said electron gun including a tubular electrode coaxially mounted on said axis and having a wall portion closing the end of said tubular electrode facing said target, said wall portion having a plurality of apertures therethrough with said apertures symmetrically spaced from said axis, with one of said apertures in the path of each of said beams, said converging lens electrode means including a pair of tubular electrodes coaxially mounted and spaced along said axis from said electrode wall portion, the ratio of the length of the tubular electrode of said pair nearer said tubular electrode wall portion to the spacing of said apertures in said electrode wall portion from said axis having a minimum value of 1.4, and the ratio of the diameter of said near electrode to the spacing of said apertures from said axis having a minimum value of 4.7.

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