United States Patent [19]

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Schwartz et al.

[11] 3,895,253

[45] July 15, 1975

[54] **ELECTRON GUN HAVING EXTENDED FIELD ELECTROSTATIC FOCUS LENS**

[75] Inventors: **James W. Schwartz,** Glenview; **Wayne R. Chiodi,** Northbrook; **William A. Rowe,** Palatine; **Iva M. Wilson,** Glenview, all of Ill.

[73] Assignee: **Zenith Radio Corporation,** Chicago, Ill.

[22] Filed: **Oct. 23, 1973**

[21] Appl. No.: **408,720**

[52] **U.S. Cl.** ..... **315/13 CG;** 313/414; 313/449; 315/16

[51] **Int. Cl.** **H01j 29/48**

[58] **Field of Search** ..... 313/69 C, 70 C, 82 DF, 313/85 R, 409, 414, 444, 449, 460; 315/13 CG, 16

[56] **References Cited**

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3,651,359	5/1972	Miyaoka	313/70 C
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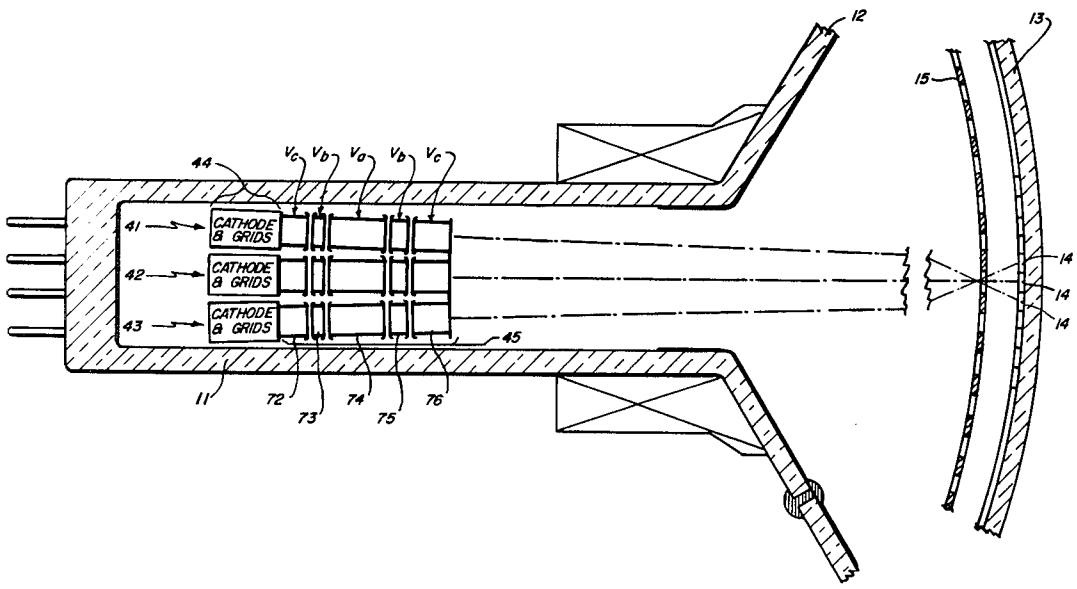
Primary Examiner—James B. Mullins

Attorney, Agent, or Firm—John H. Coult

[57] **ABSTRACT**

A color cathode ray tube includes an in-line or delta cluster of electron guns each having an improved electron focus lens. The electron lens provides reduced spherical aberration when compared with prior art electrostatic lenses having similar diameter. The lens establishes an essentially saddle-shaped axial potential distribution V_0. A plurality of coaxially and contiguously disposed electrodes have a distribution of potentials applied thereto which is highest on the end electrodes and lowest on an intermediate electrode, decreasing gradually from both end electrodes to said intermediate electrode. The lens provides an axially continuously active, stray-field isolated focusing field.

19 Claims, 9 Drawing Figures



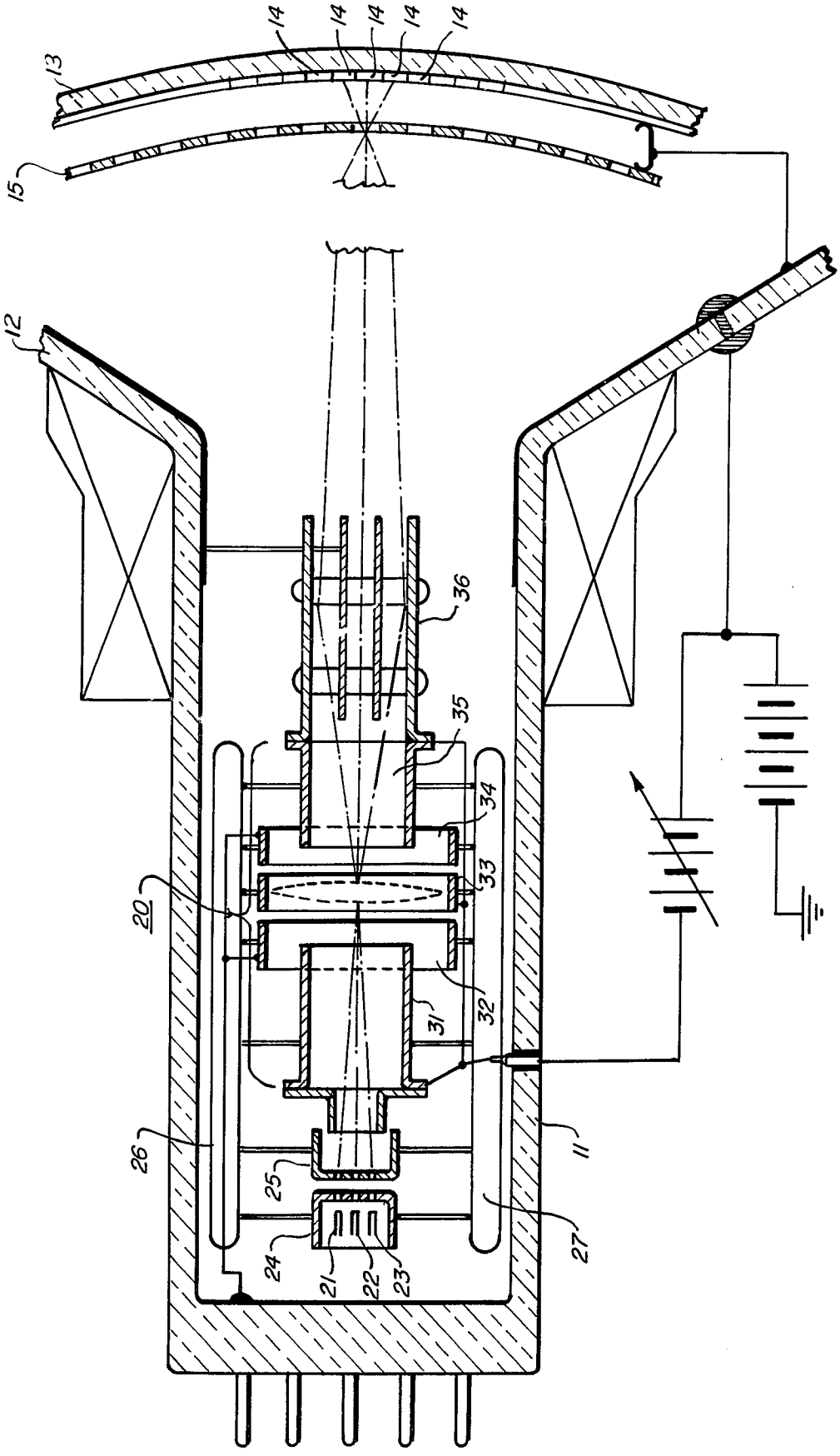


FIG. 1
"PRIOR ART"

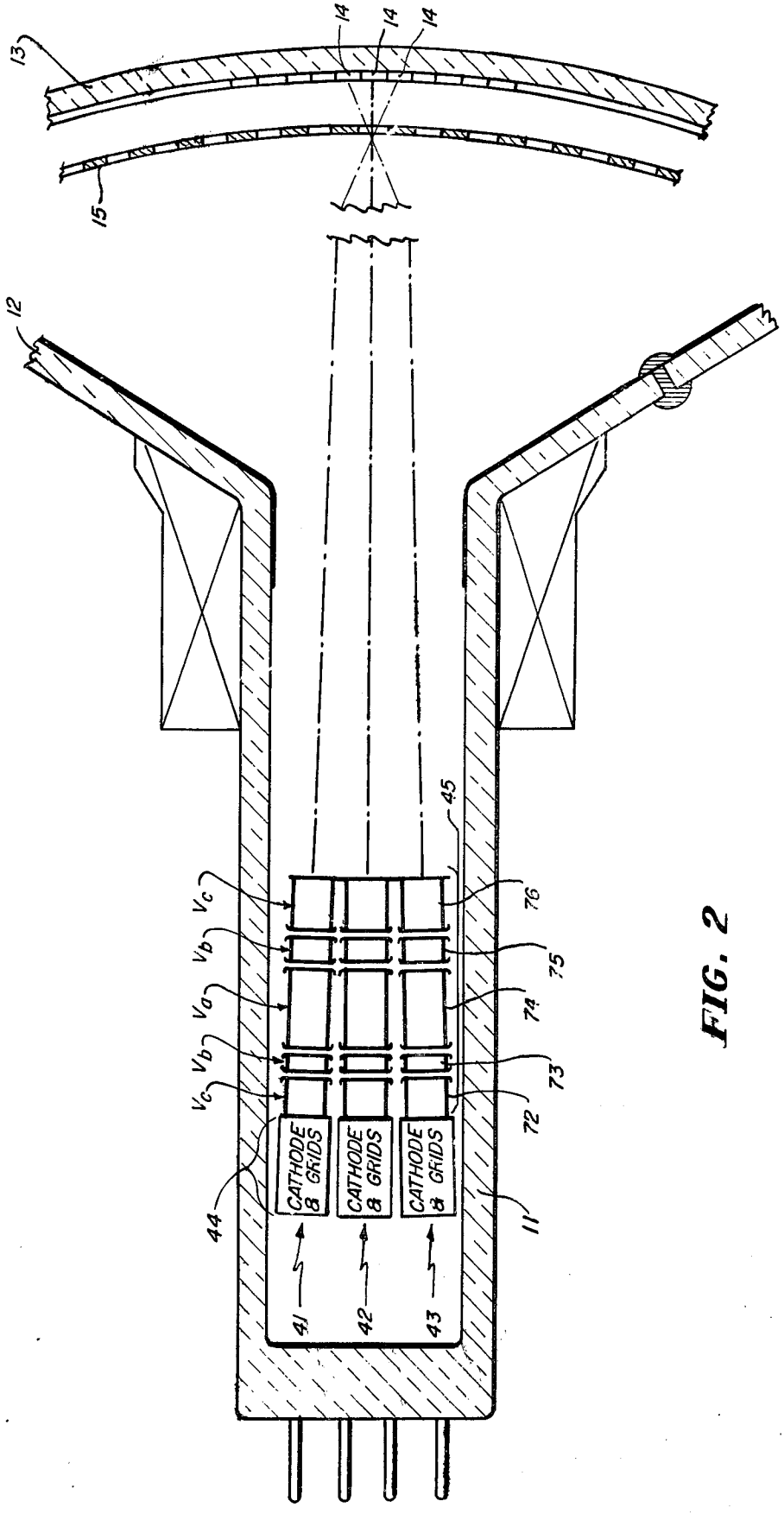

13
14
14
14
15
12
45
V_c
V_b
V_a
V_b
V_c
76
75
74
73
72
CATHODE & GRIDS
CATHODE & GRIDS
CATHODE & GRIDS
44
11
41
42
43

FIG. 2

FIG. 3

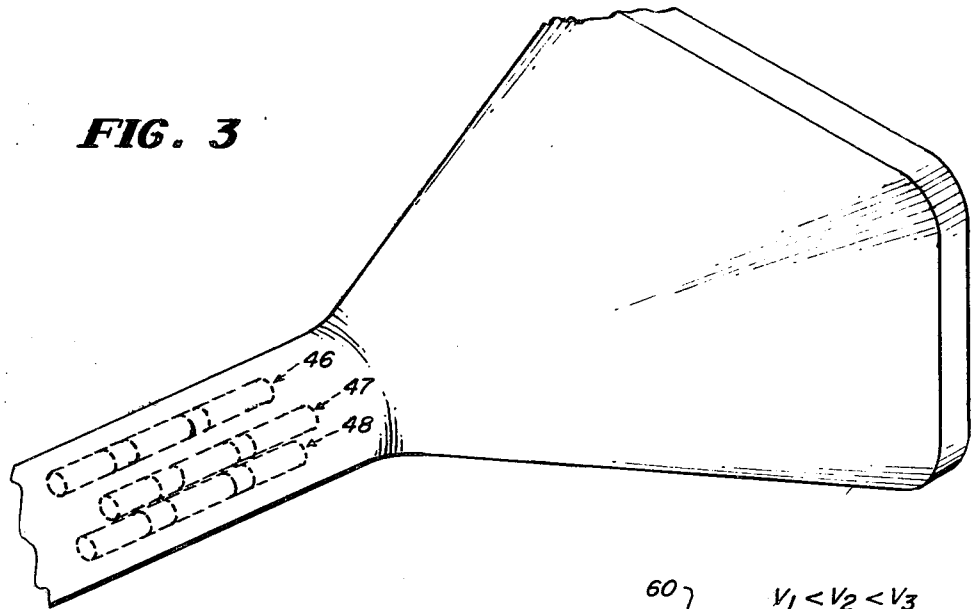
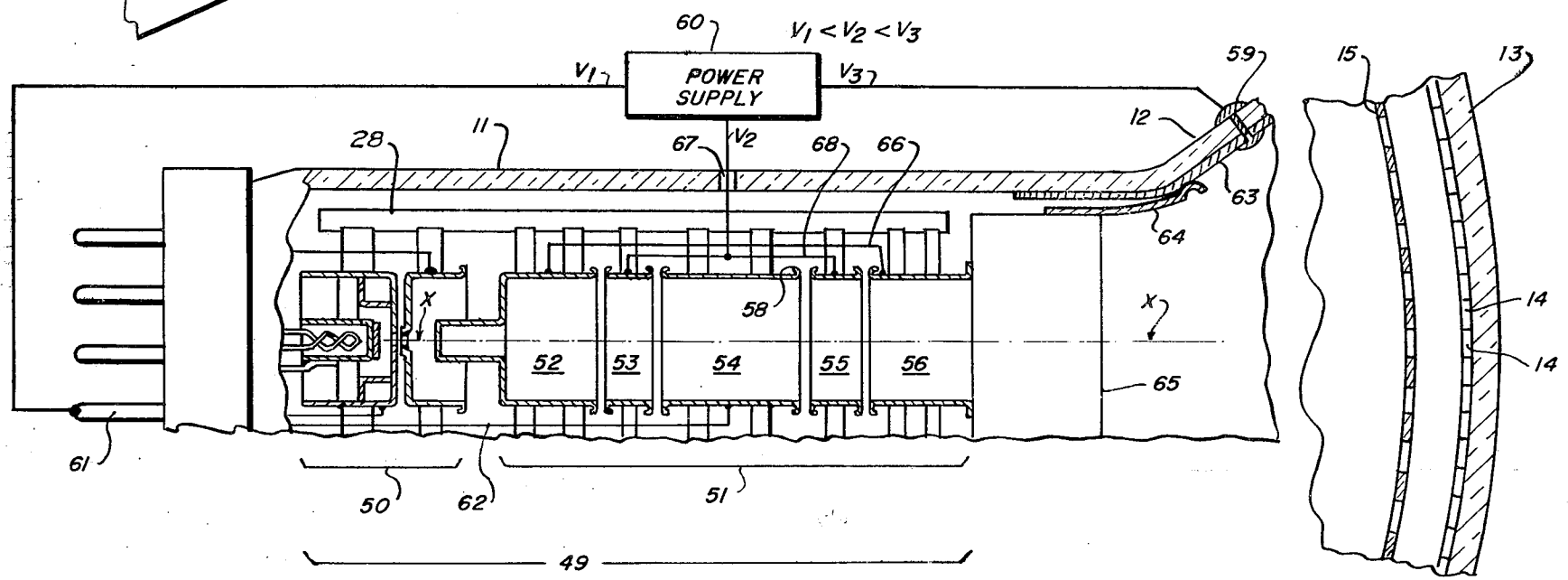


FIG. 4



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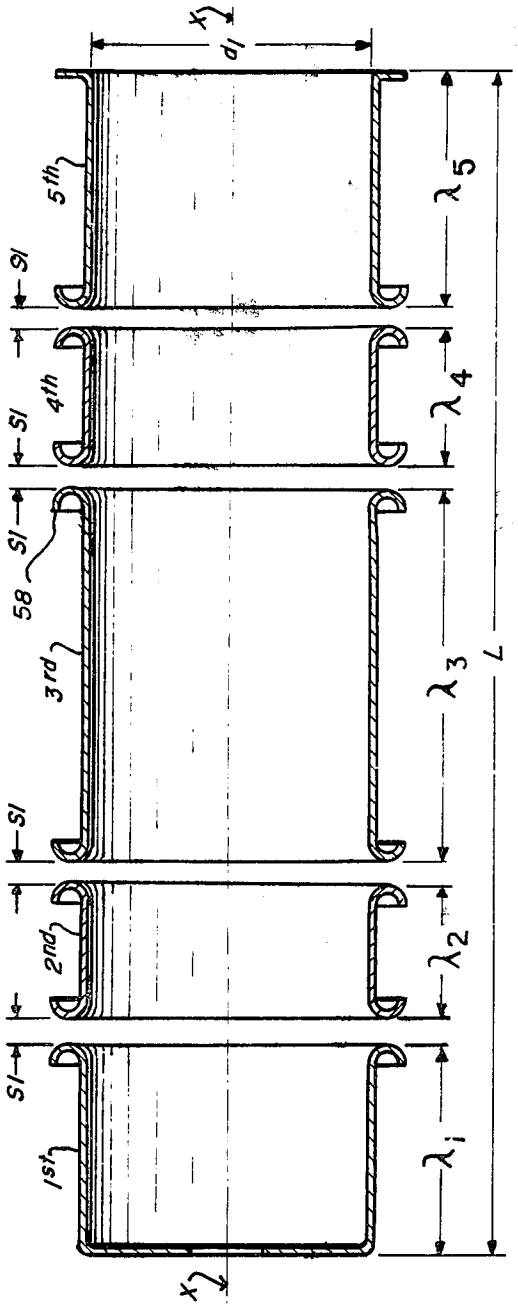

x1
d1
5th
SI
λ5
4th
λ4
58
3rd
λ3
L
2nd
λ2
1st
λ1
x2

FIG. 5

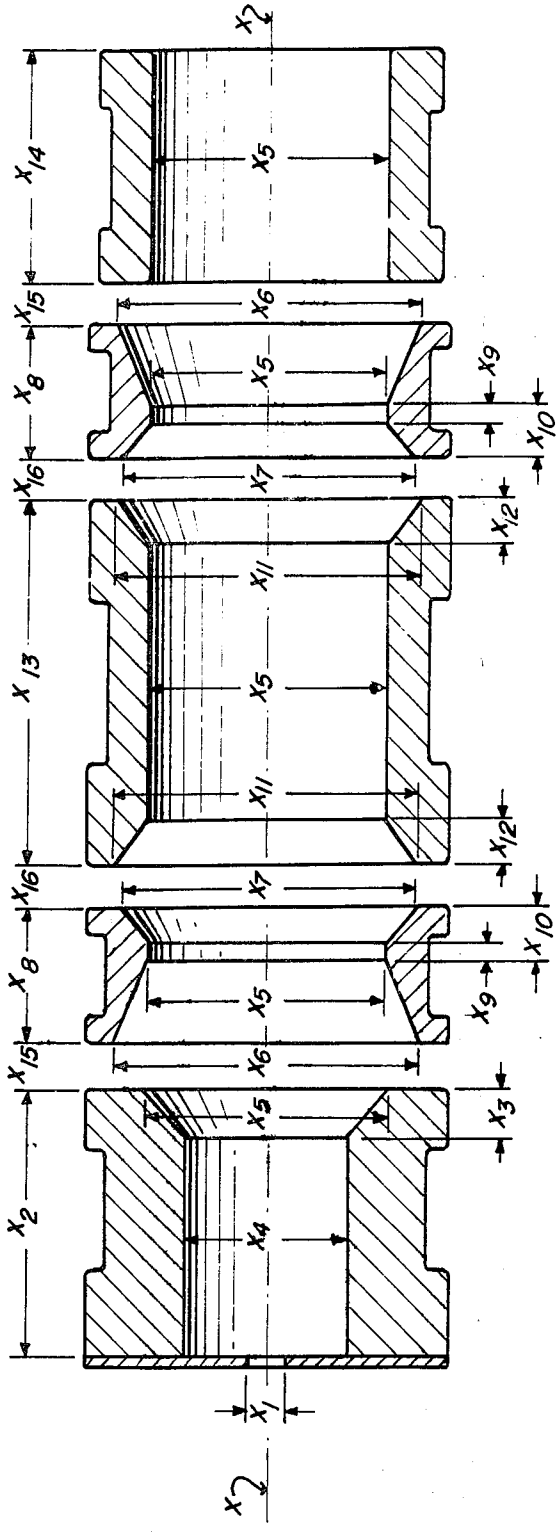
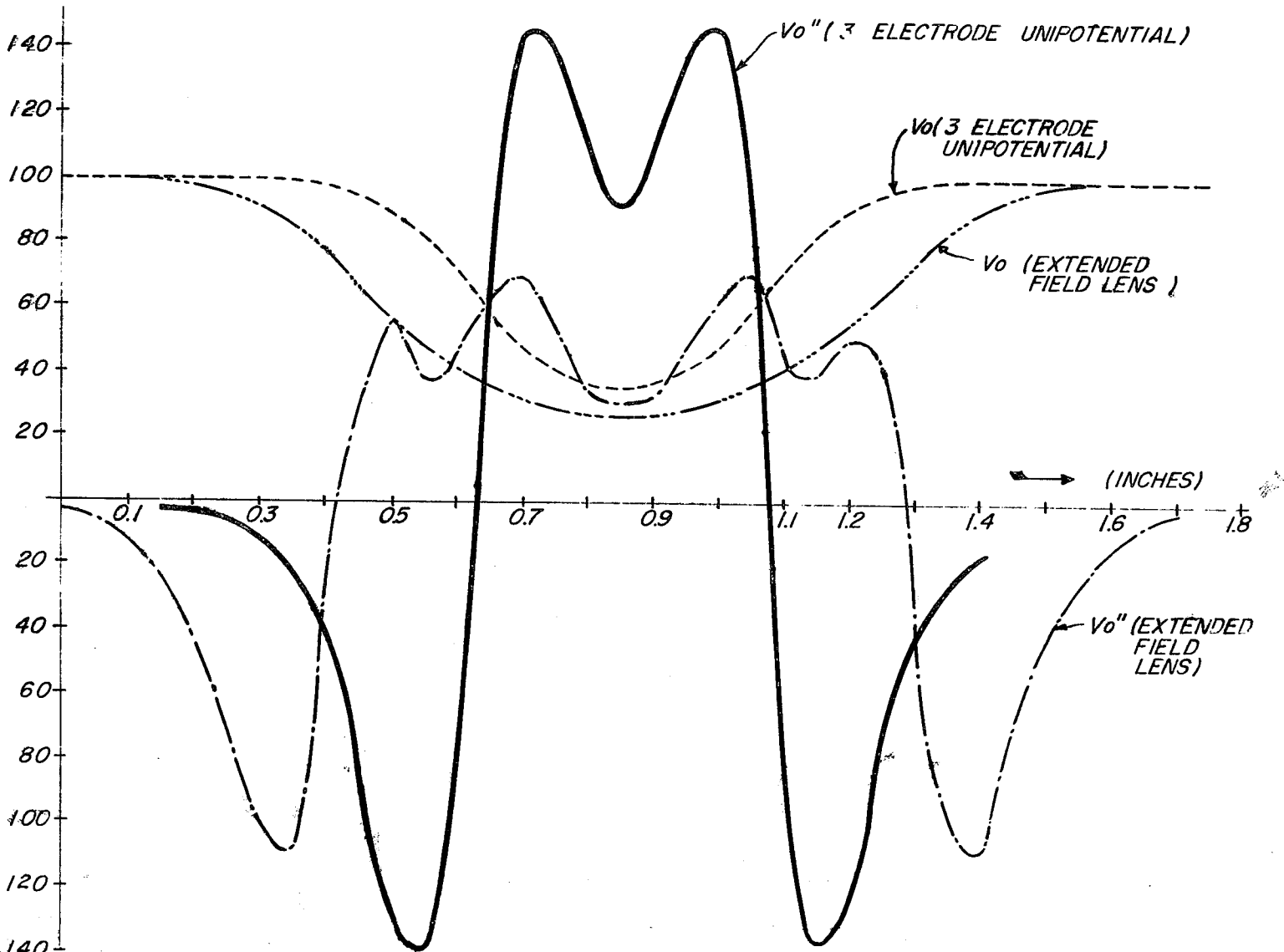

x2
x14
x5
x15
x6
x8
x9
x10
x16
x7
x12
x13
x11
x2
x4
x3
x1

FIG. 6

FIG. 7



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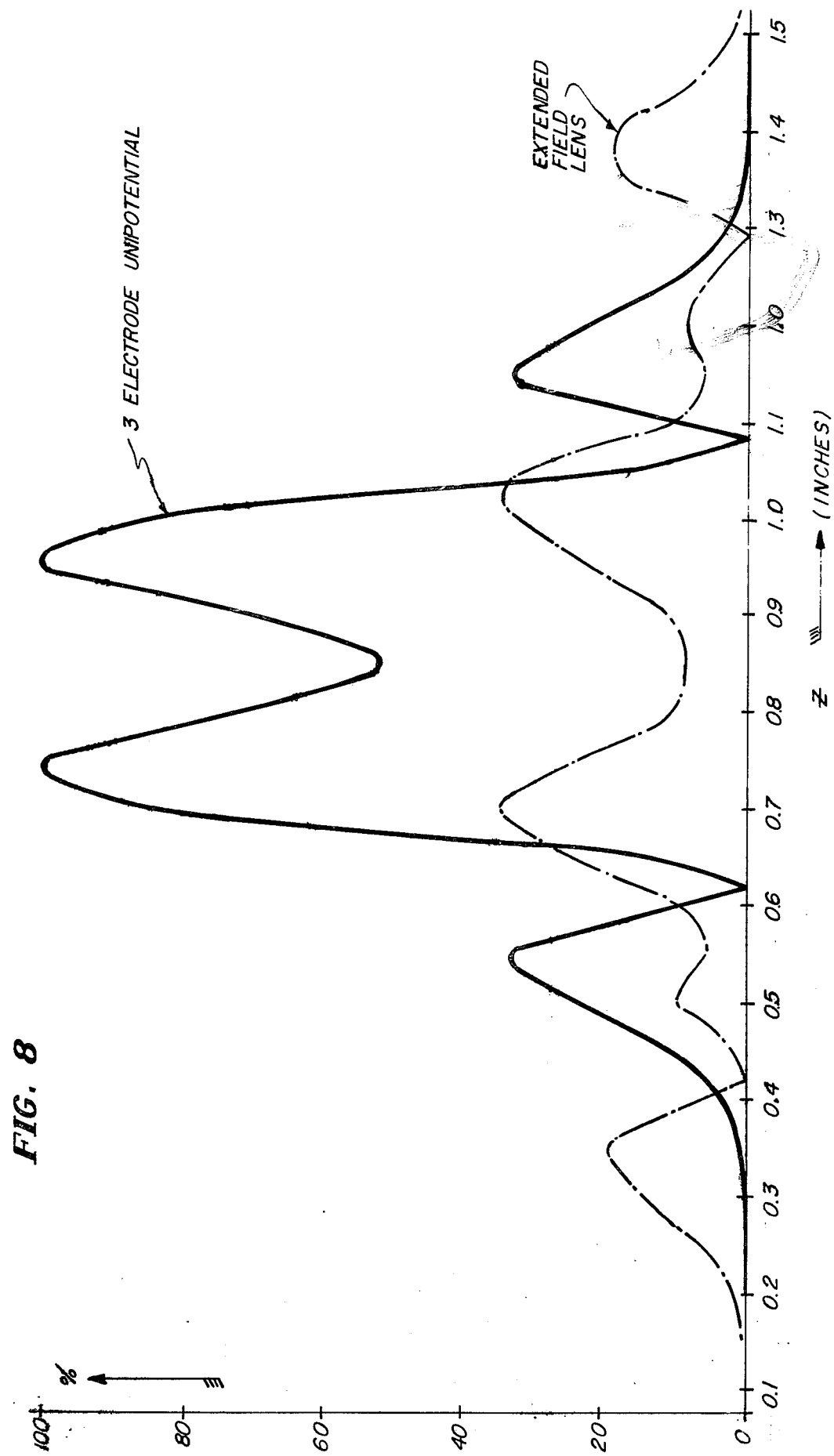

3 ELECTRODE UNIPOTENTIAL
EXTENDED FIELD LENS
%
100
80
60
40
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.3
1.4
1.5
Z (INCHES)

FIG. 8

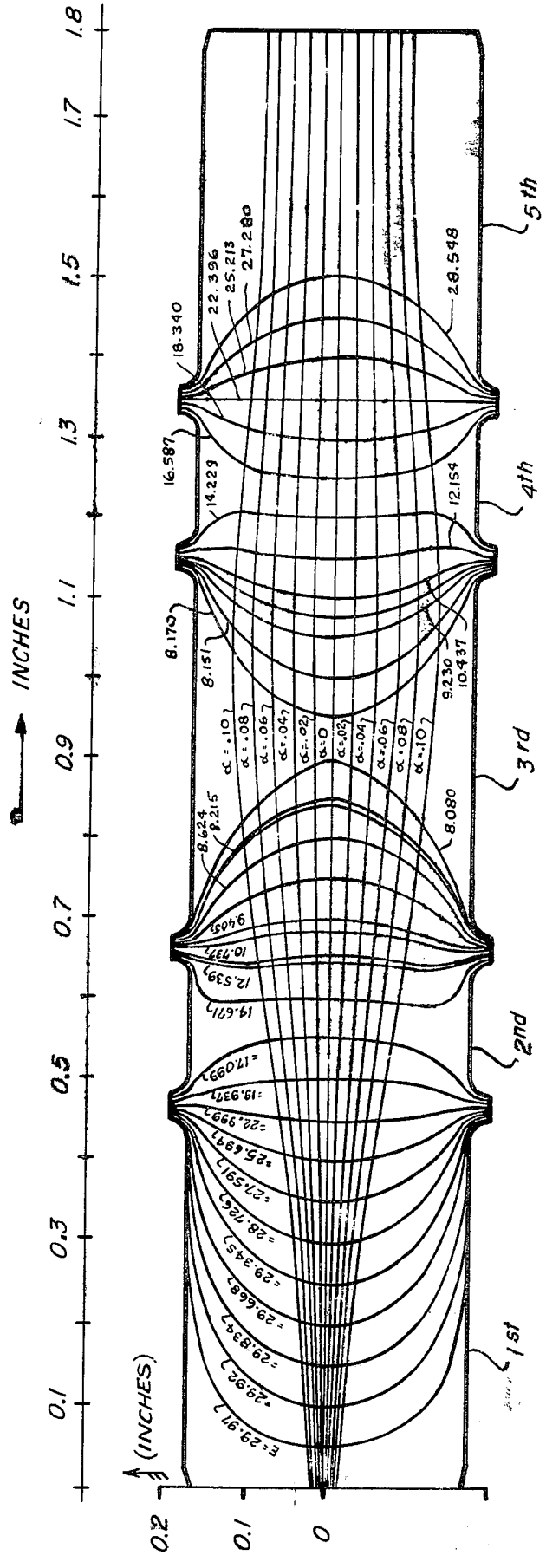

INCHES
0.1
0.3
0.5
0.7
0.9
1.1
1.3
1.5
1.7
1.8
(INCHES)
0.2
0.1
0
1st
2nd
3rd
4th
5th
18.340
22.396
25.213
27.280
28.548
16.587
14.229
12.154
8.170
8.151
9.230
10.437
8.624
8.215
8.080
9.405?
10.737
12.539
19.671
=17.099?
=19.937?
=22.999?
=25.689?
=27.591
=28.726
=29.343
=29.668
=29.839
=29.92
=29.91
α=.10
α=.08
α=.06
α=.04
α=.02
α=0
α=.02
α=.04
α=.06
α=.08
α=.10

FIG. 9

ELECTRON GUN HAVING EXTENDED FIELD ELECTROSTATIC FOCUS LENS

BACKGROUND OF THE INVENTION

Notwithstanding the present state of maturity of color television cathode ray tubes, higher quality image reproduction remains a constant objective. Specific goals of the color television industry today include pictures with improved brightness and resolution. To provide improved resolution, especially at high beam currents, requires improved means for focusing the phosphor-exciting electron beams.

Conventional color reproducing cathode ray tubes include a multi-color image screen having interspersed groups of red-emitting, blue-emitting and green-emitting phosphor elements. Excitation of these elements is provided by an in-line or delta cluster of three electron guns which emit three electron beams, each of which is focused into a beam spot on the tube screen by means of an electrostatic electron lens. The size of the electron spots focused on the screen, and thus the picture resolution, is a result of many factors. An important factor is the aberrations, particularly spherical aberration, introduced by the focus lens. In the presence of spherical aberration, all electrons emanating from an object point do not, after focusing, recombine at a common point.

Commercially available electron guns for color cathode ray tubes have focus lenses of two basic types. One type is the so-called "bi-potential" lens comprising a relatively low voltage electrode followed by a second electrode which is maintained at a relatively high voltage — typically the phosphor screen voltage.

This invention is concerned with an improvement on a second basic lens type, commonly termed the "uni-potential"-type lens comprising three electrodes, the first and third of which are maintained at the same potential, typically the screen voltage, and the second (intermediate) of which is maintained at a much lower potential.

Designers of prior art uni-potential-type lenses have reduced spherical aberration primarily by decreasing the ratio of beam diameter to lens diameter. Generally, in order to decrease this ratio the lens diameter is increased. However, this approach conflicts with the space limitations imposed by the neck diameters of standard color tube bulbs which are deliberately made small in order to minimize the yoke driving power required to deflect the beams, to minimize convergence power requirements and to minimize residual convergence errors. Neck size constraints are perhaps most severe in color tubes of the "small-neck" type having an inline cluster of three guns. For three-in-line gun clusters, the maximum diameter of the focus lens in each gun must necessarily be less than one-third of the neck inner diameter.

It has been suggested in the electron gun literature that spherical aberration of a uni-potential focus lens of the type having three closely spaced tubular electrodes may be reduced by lengthening the lens. See "Electron Optics," O. Klemperer, University Press (1953), Chapters 4, 6. However, it is recognized that there is a limit to the amount of electrode elongation which can be made in any such lens before inactive or drift regions are created in the focusing field of the lens which prevent further reduction in spherical aberration.

By increasing the separation of lens electrodes, or by using thin disc electrodes, somewhat more success may be had in reducing spherical aberration in a three electrode uni-potential lens. However, the increased gap lengths subject the focusing field to disturbance from external or stray fields. Good isolation from external fields is especially important in a plural lens color cathode ray tube because the focus field of each gun in the cluster is influentially near the other focus fields in the gun cluster.

Other techniques have been used in attempting to reduce the spherical aberration of a uni-potential-type lens. For example, U.S. Pat. No. 3,652,896 to Miyaoka discloses a three-beam electron gun having a single focus lens for all three beams. The focus lens may be described as a modification of a three electrode uni-potential lens in which a large diameter, low potential center electrode is split into two parts and an additional higher potential electrode is inserted therebetween. The result is asserted to be a lens having substantially diminished spherical aberration. Calculations have shown the Miyaoka lens, however, to lack the performance capabilities required to generate pictures having resolution meeting today's demanding standards. The Miyaoka gun also requires additional beam deflecting means between the focus lens and the cathode ray tube screen because the beams emerge from the lens along divergent, rather than convergent, paths.

As previously mentioned, improved picture resolution requires improved beam focusing means, but to provide improved resolution on a commercial basis requires not only that improved focusing means be available, but also requires that the means be commercially practicable. Uni-potential-type lenses having large numbers of electrodes may be found in the prior art but these appear to be commercially impractical. For instance, U.S. Pat. No. 2,859,378 to Gundert et al. discloses a lens comprising a plurality (21 in one embodiment) of individual, electrically conducting plates mounted in spaced parallel relationship. The plates are apertured and are impressed with voltages such that a center group of plates is excited at a relatively low potential and the remaining plates progressing from the center toward both ends are excited at successively higher voltages.

The Gundert disclosure appears mute on the subject of diminishing spherical aberration and would appear directed to solutions of other problems. Its attractiveness appears limited by such difficulties as interference between lens fields, susceptibility to stray-fields, reliability, fabrication difficulties and cost. Furthermore a very large number of discrete potentials must be supplied to the individual electrodes. This requires the additional circuitry for generating the potentials. The problem of introducing many closely spaced high voltage leads into the neck of a cathode ray tube while eliminating possible arcing is not insignificant.

OBJECTS OF THE INVENTION

It is a general object of this invention to provide an electron gun for use in television cathode ray tubes having an electrostatic focus lens which provides greatly reduced spherical aberration for a lens of given diameter and thus which provides smaller focused spot sizes and improved television picture resolution.

It is a less general object to provide a focus lens for an electron gun which has the capability described, and

yet which is susceptible of economical mass production.

BRIEF DESCRIPTION OF THE DRAWINGS

These and further objects, features and advantages of the invention will be more apparent upon reference to the following specification, claims and appended drawings wherein:

FIG. 1 is a sectional fragmentary side view of a cathode ray tube including a prior art three-beam electron gun having a single five-electrode focus lens;

FIG. 2 is a sectional fragmentary side view of a cathode ray tube including an in-line array of focus lenses constructed in accordance with this invention;

FIG. 3 is a schematic perspective view showing a lens of the invention arranged in delta array;

FIG. 4 is a sectional fragmentary side view of a color cathode ray tube including a gun which has as a part thereof a focus lens representing a preferred embodiment of the invention;

FIG. 5 is an enlarged sectional side view of a general representation of the electron lenses illustrated in FIGS. 2 and 4;

FIG. 6 is a sectional side view of an electron focus lens representing an alternative embodiment of the invention;

FIG. 7 shows an axial potential distribution V_0 and the second derivative thereof, V_0'', of a prior art lens and of an embodiment of this invention.

$$\frac{V_0''}{V_0 3/2}$$

lens and of an embodiment of this invention; and

FIG. 9 shows computer-calculated equipotential lines and electron trajectories for an embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings in detail and initially to FIGS. 1 and 2 thereof, it is seen that in each Figure a color cathode ray tube comprises a glass envelope (only partially shown) having a neck **11** and a cone **12** extending from the neck **11** to a color screen **13** provided with the usual arrays of red-emissive, blue-emissive and green-emissive phosphors **14R**, **14B**, **14G** and with an apertured beam selecting mask **15**. The color cathode ray tubes of FIGS. **1** and **2** each include means disposed within the neck **11** for generating and focusing three electron beams.

FIG. **1** represents a prior art approach employing a single lens **20** to focus three electron beams emanating from cathodes **21**, **22** and **23** and grids **24** and **25**. Also shown are conventional mounting beads **26** and **27** for supporting the electron gun. The prior art lens of FIG. **1** comprises five consecutively disposed electrodes, **31**, 32, 33, 34 and **35** impressed with a distribution of potentials which is high at end and center electrodes **31**, 35, 33 and which is low at intermediate electrodes **32**, 34. Electrodes **32**, **33** and **34** consume a substantial fraction of the radial dimension within the neck **11**. The three electron beams exit the lens along divergent paths and are reconverged by the beam converging system **36**.

As will be pointed out below, a number of structures are contemplated for implementing the principles of the invention; FIG. **2** depicts a preferred embodiment thereof. For the sake of clarity in describing the invention, certain necessary structures are omitted from FIG. **2**, such as support beads, voltage supply and leads and cathode and grid structural details.

In FIG. **2** the system of beam generation and focusing according to this invention is illustrated as comprising an in-line array of three separate electron guns **41**, **42**, 43. Each gun includes a cathode and grid system **44** (shown schematically) and a novel lens **45** constructed according to the teachings of this invention. The three guns of FIG. **2** are appropriately tilted to effect the desired convergence. Each lens **45** includes five electrodes **72**, **73**, **74**, **75**, **76** impressed with voltages V_a, V_b, and V_c as schematically represented. In contrast to the FIG. **1** prior art lens, $V_c > V_b > V_a$. As will be described in much greater detail later in this specification, in accordance with this invention, the lenses **45** each constitute a unipotential-type extended field lens having an essentially saddle-shaped distribution of axial potential. By the application of this invention, a cluster of electron guns can be constructed, which is small enough to fit in the neck of a standard color cathode ray tube, each of which guns is capable of focusing a picture of improved resolution in spite of the small focus lens diameter permitted.

Whereas FIG. **2** illustrates an execution of this invention in a color cathode ray tube having an in-line cluster of guns, the principles of the invention may be equally utilized in delta gun arrays. FIG. **3** depicts a color cathode ray tube having in the neck thereof a delta cluster of electron guns **46**, **47** and **48**. As in the FIG. **2** embodiment, the electron beams generated by the guns are converged at a shadow mask (not shown) which serves to shadow a phosphor screen (not shown) from the beams, all as is well known. The guns **46**, **47** and **48** each include a novel focus lens constructed in accordance with this invention, shown in detail in FIG. **4** and discussed at length below.

FIG. **4** shows an electrically connected, beaded gun **49** comprising one of a delta array of guns mounted in the neck of a color cathode ray tube. Reference will also be made to FIG. **5** which depicts a general representation of preferred lens embodiments typified by the FIG. **2** guns **41**, **42** and **43** and the FIG. **4** gun **49**.

The gun **49** of FIG. **4** includes a cathode and grid system **50** and a preferred focus lens **51**. Lens **51** includes first, second, third, fourth and fifth hollow cylindrical electrodes **52**, **53**, **54**, **55** and **56**. The electrodes are aligned along a common gun axis X—X by means of glass beads, one of which is shown at **28**. Each electrode is sufficiently axially separated from adjacent electrodes to preclude arcing therebetween upon application of appropriate operating potentials (to be described hereinafter), and yet the gaps are maintained small to provide good field isolation. Typically, electrode separation is about 0.03 inch.

As is commonly practiced, the electrode ends are curled to reduce occurrences of arcing between electrodes, for example, as shown at **58**. All electrodes are preferably constructed from a standard tubular 0.008 inch thick electrode material. The electrodes are impressed with potentials which progressively increase from a relatively low potential on the center (third) electrode **54** to a relatively high potential on the end (first and fifth) electrodes **52**, **56**.

As is shown in FIG. **4**, appropriate connections are made between the electrodes **52–56** and an external

power supply **60.** As depicted in FIG. **4,** center electrode **54** is supplied with a potential V_1, a relatively low potential, via a tube pin **61** and lead **62.** The end electrodes **52** and **56** receive a potential V_3 from supply **60,** a relatively high potential which is preferably substantially equal to anode (screen) potential, by way of the envelope-implanted high voltage button **59,** the internal coating of colloidal graphite **63,** snubber spring **64,** and convergence cage **65.** Lead **66** connects electrodes **52** and **56.** Intermediate electrodes **53** and **55** receive a relatively intermediate potential V_2, via an additional intermediate voltage button **67** in the neck **11** of the tube and lead **68.** Other appropriate approaches of supplying and applying the potentials will be apparent to those skilled in the art. For example, rather than using a button on the neck of the tube, the described relatively intermediate voltage may be supplied to the focus lens through an intermediate voltage pin at the base of the tube.

In employing the principles of the invention, appropriate selections are made for lens and electrode lengths, electrode diameter and electrode potentials. Lens **51** of FIGS. **4–5** has been constructed with the following dimensions (see FIG. **5** for a definition of the dimensional designators).

FIGS. **4–5** lens of delta gun application

λ_1 = .265 inch	λ_4 = .165 inch
λ_2 = .165 inch	λ_5 = .300 inch
λ_3 = .460 inch	d_1 = .350 inch
	s_1 = .030 inch

Generally speaking lens diameter is chosen as the maximum value which is spatially permitted by a particular application in a particular tube neck. For example, and as earlier mentioned, for three-in-line gun clusters, the maximum diameter of the focus lens of each gun must necessarily be less than one-third of the neck inner diameter. Analogous constraints exist for delta applications. Furthermore, it is preferred that, in any particular embodiment, all electrode diameters be equal.

In the particular lens **51** depicted in FIGS. **4** and **5,** electrodes **53** and **55** are equal in axial length (i.e., using FIG. **5** definitions, $\lambda_2=\lambda_4$). Also the axial length of each of electrodes **53, 55** is about 0.47 times its inner diameter. Generally speaking the length equality is not necessary but the axial length of each of these intermediate electrodes is preferably less than 1.5 times its diameter.

The axial length λ_3 of central electrode **54** of FIGS. **4–5** lens **51** consumes about 31% of total lens length L and is about 1.3 times its inner diameter. As a general rule it is preferable for central electrode axial length λ_3 to equal about 30% to 40% the total lens length and to range from about 0.5 to 2.0 times its diameter.

With regard to potentials selected for application to the electrodes, it has been determined that best results are obtained with voltages V_1, V_2, V_3 which progress upwardly from center electrode **54** toward end electrodes **52, 56** in approximately geometrically progressive fashion. In other words, it is preferred that V_1, V_2 and V_3 correspond approximately to the first three terms of a sequence of the form α, $\alpha\beta$, $\alpha\beta^2$, $\alpha\beta^3$ . . .

Thus, using this expression with $V_1=\alpha$, $V_2=\beta V_1$, and $V_3=\beta^2 V_1$, each voltage differs from the preceding voltage in the sequence by a progression factor (i.e., constant multiplier) of β.

A progression factor of approximately $\beta=2$ has been experimentally determined to be preferred.

The following list describes the preferred voltage ranges:

Designated Voltage	Voltage Applied to	% of Anode Voltage
V_3	End electrodes 52, 56	Approx. 100
V_2	Intermediate electrodes	Approx. 50 ± 20
V_1	Central electrode 54	Approx. 25 ± 10

Operating Condition: Although the preferred voltage ranges listed for V_2 and V_1 slightly overlap, for any particular operating set of voltages (V_3, V_2, V_1), V_1 is never greater than V_2. In other words, the progression from V_1 to V_2 to V_3 is always monotonic.

It is to be borne in mind that the lens **51** depicted in FIGS. **4–5** is only one of the many possible embodiments which may be constructed to employ the principles of the invention. For instance, referring back to FIG. **2,** each lens **45** adapted for in-line application as shown includes first, second, third, fourth and fifth hollow cylindrical electrodes **72, 73, 74, 75** and **76** analogous to the lens **51** of FIGS. **4–5.** The dimensions for lens **45** of FIG. **2** are listed below. Refer to FIG. **5** for definition of dimensional designators.

FIG. **2** lens of in-line gun application:

λ_1 =.230 inch	λ_4=.160 inch
λ_2=.100 inch	λ_5=.290 inch
λ_3=.490 inch	s_1=.030 inch
	d_1=.270 inch

Comparison of the FIG. **2** and FIGS. **4–5** embodiments highlights some of the variations possible within the scope of the invention. First it is seen that lens diameter for the FIG. **2** in-line application is substantially smaller than the FIGS. **4–5** delta application. Lens and electrode lengths for the two embodiments are different. It is also seen that the axial length of the second and fourth electrodes **73** and **75,** unlike the FIGS. **4–5** embodiments, are unequal. Otherwise the FIG. **2** and FIGS. **4–5** embodiments share many similarities. Intermediate and center electrode ratios of axial length to inner diameter fall within the previously mentioned preferred ranges. Also the voltages V_a, V_b, V_c applied to individual electrodes of the FIG. **2** lens **45** are selected by the same criteria as potentials V_1, V_2 and V_3 described in connection with FIG. **4.**

As a general rule in the embodiments such as FIG. **2** lens **45** wherein λ_2 is unequal to λ_4, it is preferred that λ_2 be the lesser of the two. The underlying rationale will be presented below in connection with a discussion of the theory of operation of focus lenses according to this invention.

Continuing briefly with other variations permissible within the principles of the invention, FIG. **6** depicts yet another alternative lens embodiment whose dimensions (in inches) are as follows:

X_1=.044 inch	X_6=.390 inch	X_{11}=.400 inch
X_2=.330 inch	X_7=.370 inch	X_{12}=.050 inch
X_3=.060 inch	X_8=.165 inch	X_{13}=.460 inch
X_4=.200 inch	X_9=.020 inch	X_{14}=.300 inch
X_5=.300 inch	X_{10}=.045 inch	X_{15}=.050 inch
		X_{16}=.045 inch

Operationally, the embodiments of FIGS. 5 and 6 are substantially the same. However, due to the axially varying inner diameter, the structure of FIG. 6 provides some additional control over the internal field established.

The greatly reduced spherical aberration provided by the extended field lens may be explained in terms of electric field theory and more particularly in terms of axial potential distribution established. (See Maloff and Epstein, *Electron Optics in Television*, McGraw Hill Book Company, 1938.) Theoretically, the vector force on electrons and resultant trajectories can be determined from a knowledge of the spatial potential distribution within the lens. Potential distribution for an axially symmetric field may be determined by solving the equation

$$\frac{\delta^2 V}{\delta r^2} + \frac{1}{r}\left(\frac{\delta V}{\delta r}\right) + \frac{\delta^2 V}{\delta z^2} = 0,$$

where $V=V(r,z)$=potential function of an axially symmetric electrostatic field, z=lens axial coordinate, r=lens radial coordinate, subject to the boundary conditions that V assume the given values of potential on the electrodes.

In general it is not possible to obtain simple analytic solutions of the above equation subject to the actually existing boundary conditions. However, the spatial potential distribution within an axially symmetric lens can also be determined from a knowledge of axial potential $V_0(z)$ [where $V_0(z)=V(0,z)$], and its even order derivatives with respect to z

$$V(r,z)=V_0(z) - \frac{V_0'' r^2}{4} + \frac{V_0'' r^4}{64} - \cdots$$

where

$$V_0^{n} \equiv \frac{\delta^n V_0}{\delta z^n}$$

It can be shown that lens aberrations depend largely on the value of the line integral of the quantity

$$\left[\frac{(V_0'')^2}{(V_0)^{3/2}}\right] r^4.$$

Therefore, it follows that large values of V_0'' are particularly harmful in regions where the axial potential V_0 is low or where beam radius is large. FIGS. 7 and 8 illustrate certain findings and compare an embodiment of the present invention with a well designed conventional three electrode unipotential lens having the same diameter. As is seen from FIG. 7 the axial potential distributions V_0 of both lenses are generally saddle-shaped. It is also seen, however, that for the extended field lens of this invention V_0'' is substantially less over the entire lens length and is especially low in regions of low axial potential. Furthermore, the maximum values of V_0'' are substantially reduced.

$$\frac{(V_0'')^2}{(V_0)^{3/2}}$$

lens. Each curve is normalized with respect to the maximum value of

$$\frac{(V_0'')^2}{(V_0)^{3/2}}$$

The substantial reduction is this quantity is an indication of the substantial reduction in spherical aberration provided in accordance with the principles of the invention. It should be noted at this time that the focusing field of the extended field lens is axially continuously active. For instance, a reduction in V_0'' alone especially in regions of low axial potential might be achieved with a "complete lens" formed by placing two bi-potential lenses essentially back to back separated by some axial distance. However, any reduction in V_0'' would also likely be accomplished by the establishment of a drift or inactive focusing region at the composite lens center due to the axial separation of said bi-potential lenses.

For some idealized embodiments significant equi-potential lines and electron trajectories from an on-axis object point have been computed. FIG. 9 graphically represents such computations for a lens having the following dimensions and applied potentials:

λ_1=.450 inch	$V_1=7.6 \times 10^3$ volts
λ_2=.165 inch	$V_2=15 \times 10^3$ volts
λ_3=.460 inch	$V_3=30 \times 10^3$ volts
λ_4=.165 inch	
λ_5=.450 inch	
s_1=.030 inch	
d_1=.350 inch	

Alpha is the electron trajectory angle from the object point. E is the value of the designated equi-potential line in kilovolts. Object distance is 1 inch.

FIG. 9 summarizes much of what has been said above. The small gap (30 mils) is large enough to preclude arcing, yet is small enough such that the focusing field is well shielded from any external field disturbances. It is also apparent that the focusing field contains no drift regions and provides a greatly reduced disc of least confusion, and thus reduced spherical aberration, for a lens of its diameter.

FIG. 9 also assists in explaining an earlier made statement that when λ_2 is unequal to λ_4 it is preferred that λ_2 be the lesser of the two. Momentarily returning to theory of operation, in addition to our findings that large values of V_0'' are particularly harmful in regions where V_0 is low, we have observed that large values of V_0'' are also particularly harmful in regions where the beam diameter is large. FIG. 9 shows that the tendency of the beam is to have a large diameter in regions of the fourth electrode than in regions of the second electrode. This means that in some instances, values of V_0'' are less critical in regions of the second electrode than in regions of the fourth electrode and thus the second electrode may be shorter in axial length than the fourth.

Although certain preferred embodiments hereinabove described have included five electrodes impressed with three voltages as shown, it is presently contemplated that the principles of the invention may be otherwise embodied. For instance, in accordance with the above rationale regarding inequality of second and fourth electrode axial length, it is presently contemplated that for some applications the second electrode could be eliminated altogether, leaving in substance a four electrode extended field type lens. Also it is contemplated that substitution of plural electrodes

for any one of the five electrodes could be made. For example, any electrode could be divided and the segments impressed with only slightly different voltages from those described above but in the same basic axial scheme or direction as those of the preferred embodiments.

Moreover, although many of the preferred lens embodiments have been described herein as being constructed from standard tubular electrode material, it may be desirable in certain instances of plural gun application to construct the corresponding electrodes from a common piece of electrically conductive material. For instance, in a delta or three-in-line configuration, all three first electrodes could be stamped, machined, or otherwise constructed from a single block of material. In other words, instead of having three individually distinct first electrodes, one block of material would have three cylindrical channels appropriately dimensioned, appropriately spaced from each other, appropriately axially converging, and appropriately arranged either in delta or in-line fashion. All three second electrodes could likewise be made from a single block of material, and so forth for the remaining electrodes. Other structural modifications may be employed to achieve focusing fields equivalent to those achieved by preferred embodiments herein. It should also be appreciated that although the foregoing description has presumed an application of the principles of the invention in a color cathodc ray tube environment, the same principles are applicable and the advantages likewise enjoyed in black and white cathode ray tubes. Thus it is to be understood that changes and variations according to the principles of this invention may be made on the above-described embodiments by one skilled in the art without departing from the true spirit and scope of this invention.

We claim:

1. In combination:

an electron gun constituting one of a delta or three-in-line gun cluster in the neck of a color cathode ray tube, said gun having a focus lens providing reduced spherical aberration for a given lens inner diameter, said focus lens comprising in closely spaced coaxial relationship:

first and fifth end electrodes receiving substantially equal, relatively high applied potentials,

second and fourth intermediate electrodes receiving substantially equal, relatively intermediate applied potentials, and

a central third electrode receiving a relatively low applied potential; and

means for supplying and applying said potentials to said electrodes.

2. The lens defined by claim **1** herein the applied potentials progress upwardly from said central electrode to said second and fourth intermediate electrodes and from said second and fourth electrodes to said first and fifth end electrodes in approximately geometrically progressive fashion.

3. The lens defined by claim **2** wherein the progression factor is approximately 2.

4. The lens defined by claim **1** wherein said relatively intermediate potential is in a range from about 30 to 70% of said relatively high potential, said relatively low potential is in a range from about 15 to 35% of said relatively high potential, and the progression from said relatively low potential to said relatively intermediate potential to said relatively high potential is monotonic.

5. The lens defined by claim **1** wherein said central electrode has an axial length of about 0.5 to about 2.0 times its inner diameter.

6. The lens defined by claim **1** wherein all of said electrodes have an equal inner diameter.

7. The lens defined by claim **1** wherein each of said intermediate electrodes has axial dimension which is less than 1.5 times its inner diameter.

8. In combination:

an electron gun constituting one of a delta or three-in-line gun cluster in the neck of a color cathode ray tube, said gun having a focus lens comprising first, second, third, fourth and fifth hollow cylindrical electrodes coaxially, consecutively and closely disposed; and

means for supplying and applying to said first and fifth electrodes substantially equal, relatively high potentials, for supplying and applying to said second and fourth electrodes substantially equal relatively intermediate potentials, and for supplying and applying to said third electrode a relatively low potential, each of said five electrodes being axially dimensioned to establish in conjunction with said applied potentials: (i) an axially continuously active focusing region, and (ii) within a given lens diameter an axial potential distribution V_0 having substantially reduced maximum values of V_0'', where

$$V_0'' = \frac{\delta^2 V_0}{\delta z^2}$$

and z is the gun axis variable.

9. The lens as defined in claim **8** wherein said third electrode has an axial length of about 0.5 to 2.0 times its inner diameter.

10. The lens defined by claim **8** wherein each of said second and fourth electrodes has axial dimension which is less than 1.5 times its inner diameter.

11. In combination:

an electron gun constituting one of a delta or three-in-line gun cluster in the neck of a color cathode ray tube, said gun having a focus lens comprising first, second, third, fourth and fifth hollow cylindrical electrodes coaxially, consecutively and closely disposed;

means for supplying and applying to said first and fifth electrodes substantially equal, relatively high potentials, for supplying and applying to said second and fourth electrodes substantially equal relatively intermediate potentials, and for supplying and applying to said third electrode a relatively low potential, each of said five electrodes being axially dimensioned to establish in conjunction with said applied potentials: (i) an axially continuously active focusing region, and (ii) within a given lens diameter an axial potential distribution V_0

$$\frac{(V_0'')^2}{V_0^{3/2}}$$

are substantially reduced, where

$$V_0'' = \frac{\delta^2 V_0}{\delta z^2}$$

and z is the gun axis variable.

12. The lens as defined by claim **11** wherein said third electrode has an axial length of about 0.5 to 2.0 times its inner diameter.

13. The lens defined by claim **11** wherein each of said second and fourth electrodes has axial dimension which is less than 1.5 times its inner diameter.

14. For use in a television cathode ray tube having associated therewith a power supply for developing discrete supply voltages, an electron gun for receiving supply voltages from the power supply to produce a focused beam of electrons, comprising:

electron source means comprising cathode means and grid means; and

focus lens means for receiving electrons from said electron source means and a predetermined pattern of supply voltages from the power supply to form an electron spot at a distance from said electron source, comprising:

initial and final tubular end electrodes for receiving relatively high supply voltages,

a low voltage tubular electrode located between said initial and final electrodes for receiving a relatively low supply voltage, and

intermediate voltage electrode means between said low voltage electrode and at least one of said end electrodes for receiving a relatively intermediate supply voltage, said lens establishing an extended, axially continuously active focusing field which is substantially shielded from external field disturbances and establishing an axial potential distribution which decreases steadily in value from said initial end electrode to said low voltage electrode and increases steadily in value from said low voltage electrode to said final end electrode.

15. For use in a color television cathode ray tube having associated therewith a power supply for developing discrete supply voltages, an electron gun of the type constituting one of a delta or three-in-line gun cluster for receiving supply voltages from the power supply to produce a focused beam of electrons, comprising:

electron source means comprising cathode means and grid means; and

main focus lens means for receiving electrons from said electron source means and a predetermined pattern of supply voltages from the power supply to form an electron spot on the screen of the tube, comprising, in closely spaced relationship:

first and fifth end electrodes for receiving substantially equal, relatively high supply voltages,

second and fourth intermediate electrodes for receiving substantially equal, relatively intermediate supply voltages, and

a central third electrode for receiving a relatively low supply voltage.

16. The lens defined by claim **15** wherein said relatively intermediate supply voltage is in a range from about 30 to 70% of said relatively high supply voltage, wherein said relatively low supply voltage is in the range from about 15 to 35% of said relatively high supply voltage but always lower than said relatively intermediate supply voltage, and wherein the progression from said relatively low supply voltage to said relatively intermediate supply voltage to said relatively high supply voltage is monotonic.

17. The lens defined by claim **15** wherein said central electrode has an axial length of about 0.5 to 2.0 times its inner diameter.

18. The lens defined by claim **15** wherein all of said electrodes have an equal inner diameter.

19. The lens defined by claim **15** wherein each of said intermediate electrodes has an axial dimension which is less than about 1.5 times its inner diameter.

* * * * *

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,895,253 Dated 7-15-75

Inventor(s) James W. Schwartz, Wayne R. Chiodi, William Rowe and Iva M. Wilson

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In column 3, lines 30-34 should start a new paragraph and read --Figure 8 shows the distribution $\frac{V_0''}{V_0^{3/2}}$ of a prior art lens and of an embodiment of this invention; and--

In column 7, lines 63-68 should read --Figure 8 is a comparison of

$$\frac{(V_0'')^2}{(V_0)^{3/2}}$$

for each of the lens. Each curve is normalized with respect to the maximum value of--

In column 8, lines 1-5 should read -- $\frac{(V_0'')^2}{(V_0)^{3/2}}$ of the three electrode unipotential lens.--

In column 8, line 12, "complete" should read --composite---

In column 10, add missing line 60 as follows --such that maximum values of--

Signed and Sealed this

Twenty-first Day of September 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

PO-1050
(5/69)

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