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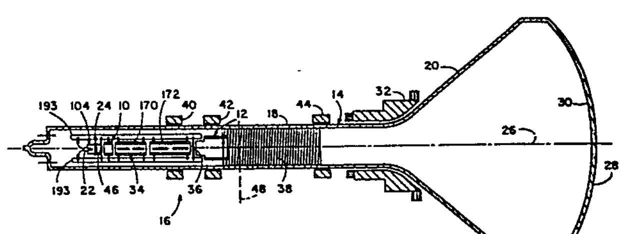
(54) **Multiple beam electron discharge tube having beam convergence and beam-to-beam compression compensation.**

(57) The invention concerns a multiple beam electron discharge tube (16) comprising beam-producing means (24) for producing plural beams of electrons directed along a beam axis (26) in the tube (16) toward a display screen (28, 30) positioned at one end of the tube (16); deflection means (32) for deflecting the electron beams relative to the beam axis (26) to produce an image on the display screen; convergence means positioned between the beam-producing means (24) and the deflection means (32) for converging the electron beams, the convergence means including a first electrode structure (10) that is electrically isolated from and positioned upstream of a second electrode structure (36) that has a limiting aperture through which the electron beams propagate; and first biasing means for providing between the first and second electrode structures a first potential difference of an amount that directs through the limiting aperture a substantial number of the electrons in each one of the beams.



MULTIPLE BEAM ELECTRON DISCHARGE TUBE HAVING BEAM CONVERGENCE AND BEAM-TO-BEAM COMPRESSION COMPENSATION

Background of the Invention

The present invention relates to electron beam discharge tubes and, in particular, a multiple beam cathode-ray tube that employs compensation electrode structures for increased beam convergence and reduced beam-to-beam compression to provide a bright, high resolution display image.

Multiple beam cathode-ray tubes generate, scan, and focus a plurality of electron beams as a group. Cathode-ray tubes of this type are capable of displaying pixel data of high brightness at relatively high pixel data rates. Multiple beam cathode-ray tubes suffer, however, from brightness losses resulting from problems with improper beam convergence and unacceptable beam-to-beam compression. The problem of improper convergence arises whenever a bundle of electron beams propagates toward a limiting aperture electrode along a path that causes some of the electrons in the beams to strike the periphery of, and therefore not pass through, the aperture. The problem of beam-to-beam compression is observed on a display surface as the narrowing of the vertical distance separating adjacent horizontal lines formed by the scan of the electron beams. This compression worsens as the current of an individual beam, or the image brightness, is increased. Each of these problems causes a reduction in beam current, which results in a diminution of image brightness.

Summary of the Invention

An object of this invention is, therefore, to provide a multiple beam cathode-ray tube in which a beam convergence electrode structure converges the bundle of electron beams in a manner such that a substantial number of the electrons pass through a limiting aperture electrode to increase beam current and provide a bright, high resolution display image.

Another object of this invention is to provide in such a cathode-ray tube a beam-to-beam compression compensating electrode structure that develops a bright, high-quality image.

Additional objects and advantages of the present invention will be apparent from the following detailed description of a preferred embodiment thereof, which proceeds with reference to the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a schematic longitudinal section view of a multiple beam cathode-ray tube incorporating beam convergence and beam-to-beam compression compensation electrode structures in accordance with the present invention.

Fig. 2 is a diagram showing an array of grid electrode apertures that produce integer multiples of pixel spacing in both the horizontal and vertical directions on the display surface of the cathode-ray tube of Fig. 1.

Fig. 3 is an enlarged cross sectional view of the grid electrode structure included in the glass neck of the cathode-ray tube of Fig. 1.

Fig. 4 is a diagram showing the surface of the control grid electrode that is included in the grid electrode structure of Fig. 3.

Fig. 5 is an enlarged side elevation view of a beam convergence electrode and a drift tube section that receive eight electron beams which emerge from the grid electrode structure in the cathode-ray tube of Fig. 1.

Fig. 6 is an illustration of beam-to-beam compression that results from high levels of beam current.

Detailed Description of Preferred Embodiment

With reference to Fig. 1, a beam convergence compensating electrode structure 10 and a beam-to-beam compression compensating electrode structure 12 of the present invention are contained within an evacuated envelope 14 of a multiple beam electron discharge tube 16. In a preferred embodiment, tube 16 is a cathode-ray tube with a relatively large screen (e.g., 48 cm diagonal) for a television-type monitor. Envelope 14 includes a tubular glass neck 18 and a ceramic funnel 20. A cathode 22 positioned within a glass neck 18 at one end of envelope 14 cooperates with a grid electrode structure 24 to form plural narrow writing beams of high velocity electrons.

Grid electrode structure 24 includes five spaced-apart, disk-shaped electrodes. The beams of electrons propagate along a beam axis 26 toward a display screen or surface 28 positioned on the opposite side of envelope 14. A layer 30 of phosphorescent material is coated on the inner side of display surface 28 to form a fluorescent screen for cathode-ray tube 16. The beams of electrons strike layer 30 of the phosphorescent material to form an image on display surface 28. Cathode-ray tube 16 is preferably of the magnetically deflected type having a deflection yoke 32 that includes a horizontal deflection coil and a vertical deflection coil which deflect the electron beams in the horizontal direction and the vertical direction, respectively, in a conventional raster-scan pattern.

In a preferred embodiment, a grid electrode structure 24 generates a bundle of eight individually modulated parallel beams of electrons that propagate along beam axis 26 in neck 18 to display surface 28. The eight electron beams exit grid electrode structure 24 in a generally circular off-axis array positioned around beam axis 26 and propagate through convergence electrode structure 10, which shifts their propagation paths toward beam axis 26.

The electron beams propagate through a drift tube section 34 and converge toward the center of a limiting aperture electrode 36. The length of drift tube section 34 and the magnitude of a potential difference applied to drift tube section 34 affect the magnification of the image. The converged bundle of electron beams exit limiting aperture electrode 36 and propagate through beam-to-beam compression compensating electrode structure 12, which, as the beam current increases, cooperates with grid electrode structure 24 and drift tube section 34 to maintain a uniform vertical distance between adjacent horizontal lines formed on display surface 28 by the raster-scanned electron beams. The electron beams are then accelerated by a linear helix coil 38 of constant pitch that is wound on the inner surface along the length of neck 18. An accelerating voltage of 25 kV is delivered from the anode (not shown) of cathode-ray tube 16 to the exit end of helix coil 38. The bundle of beams propagating along the length of neck 18 is subjected to conventional electromagnetic correction fields developed by rotation coils 40, astigmatism coils 42, and magnetic focus coils 44.

Grid electrode structure 24 includes an exit electrode 46 that has an array of apertures. The electron beams emitted by cathode 22 propagate through the aperture array, which forms a first array of crossovers. The first array of crossovers is made as small as practicable to minimize the amount of demagnification that is required to produce a display of the desired size. Astigmatism coils 42 control the size of the array by controlling the axial position of a second array of crossovers. For example, in a 2000 line, 25.4 cm high display, a 2.13 mm first array of crossovers of 2.13 mm diameter can be reduced to a 0.889 mm diameter. Astigmatism coils 42 accomplish this reduction by causing the array to be demagnified at the entrance of the accelerating field of helix coil 38. The second array of crossovers is then formed in a vertical plane 48 that is located about 2.54 cm into the helix. Magnetic focus coils 44, which are positioned at the downstream end of helix coil 38, image the second array of crossovers onto display surface 28. The production of the second array of crossovers facilitates a dynamic change in the array size as is required by the scanned position of the array.

An image appearing on display surface 28 comprises a series of parallel stripes. Each stripe includes plural sets of pixels spaced apart by equal distances in linear arrays along the length of the stripe. The number of electron beams corresponds to the number of linear arrays included in each stripe. Each of the linear arrays in a stripe is formed by a separate scan of one of the electron beams across display surface 28. Each stripe is formed by concurrently scanning the eight electron beams horizontally across display surface 28. The stripes in a series are, therefore, vertically stacked in raster-scan fashion on display surface 28 to synthesize an image that comprises a two-dimensional array of pixels.

Fig. 2 shows the preferred array geometry of eight pixel elements 50, 52, 54, 56, 58, 60, 62, and 64 that produce integer multiples of pixel spacing in both the horizontal and vertical directions on display surface 28. The eight pixel elements in the array represent apertures in exit electrode 46 and the other four electrodes included in grid electrode structure 24. Corresponding apertures in the electrodes are axially aligned so that the electrons emitted from cathode 22 propagate through the electrodes as a bundle of eight electron beams.

More specifically, the pixel array of grid electrode structure 24 comprises eight circular apertures 50, 52, 54, 56, 58, 60, 62, and 64 that are arranged in a generally circular off-axis pattern about a center point 66, which is coincident with beam axis 26. Adjacent apertures in both the horizontal and vertical directions are spaced apart by distances that differ by an integer multiple of a predetermined amount, "d," which in a preferred embodiment equals 0.1524 mm. The diameter of each aperture is the same and equals 0.1524 mm. The horizontal and vertical distances between the apertures are shown in Fig. 2.

As indicated in Fig. 2, scanning the electron beams horizontally produces eight horizontal lines 68, 70, 72, 74, 76, 78, 80, and 82 on display surface 28 that are vertically spaced apart by a distance "2d." As was described above, the eight lines form a stripe. Whenever the pixel array is properly rotated, demagnified, scanned, focused, and astigmatized, there is vertically uniform line-to-line pixel spacing. Whenever appropriately timed video signals are concurrently applied to scan the electron beams, there is also horizontally uniform pixel spacing across the display surface 28.

Fig. 3 is a cross sectional view of grid electrode structure 24, which produces the eight individually modulated electron beams. Grid electrode structure 24 includes coaxially aligned upper support cylinder 90 and lower support cylinder 92 which cylinders are separated by four planar grid electrodes 94, 96, 98, and 100. Ceramic annular insulators 102 electrically isolate and mechanically separate electrodes 94, 96, 98 and 100 so that a different electrical voltage can be applied to each one of them. Lower cylinder 92 supports a cathode support assembly 104 which positions cathode 22 proximally adjacent to electrode element 94. Upper cylinder 90 supports electrode 46, which, as was stated above, constitutes the exit electrode of grid electrode structure 24. Electrons emitted from cathode 22 propagate through the axially aligned apertures 50, 52, 54, 56, 58, 60, 62, and 64 in electrodes 94, 96, 98, 100, and 46 to form the eight electron beams. The electron beams exit the apertures in electrode 46 and propagate through convergence electrode structure 10, which converges the eight electron beams in the manner discribed below.

Each of the electrodes 96, 98, 100, and 46 is of a disk shape whose apertures 50, 52, 54, 56, 58, 60, 62, and 64 are electrically common to one another. Electrode 94, which is called the "control grid electrode," is of a disk shape but is designed with radial slots so that a different electrical voltage can be applied to each of the eight apertures in it.

Each of electrodes 94, 96, 98, 100, and 46 is preferably formed from a metal foil circular disk. Each of electrodes 94, 96, 98, and 100 is of approximately 0.0762 mm thickness and 13.284 mm diameter. Electrode 46 is of approximately 0.254 mm thickness and 13.284 mm diameter. Each of the electrodes is brazed to the ceramic annular insulator 102 that separates it from the next adjacent electrode, with the exception of electrode 46, which is brazed to the end of upper cylinder 90 opposite to which end electrode 100 is brazed. Each of the annular insulators 102 is approximately of 0.254 mm thickness. Upper cylinder 90 and lower cylinder 92 are approximately 5.08 mm in length and have a 5.6642 mm inner diameter.

Fig. 4 shows the construction of control grid electrode 94 that is used in the present invention. With reference to Fig. 4, control grid electrode 94 is of circular shape and is divided into eight wedge-shaped segments 108, 110, 112, 114, 116, 118, 120, and 122 that have respective conducting tabs 124, 126, 128, 130, 132, 134, 136, and 138 extending outwardly from their outer edges. The wedge segments are formed by cutting radial slots from the periphery to near the center point 156 of the electrode. As shown in Fig. 4, the slots bisect the linear distance between adjacent apertures but do not extend all the way to center point 156. Cutting the slots in this manner provides electrical isolation of the electron beams passing through the apertures of adjacent wedge segments.

The terminal points of the slots 142, 144, 146, 148, 150, and 152 that form segments 110, 112, 114, 116, 118, 120, and 122 are cut to form a generally circular center tab 153 that is connected only to segment 108. Center tab 153 blocks the flow of electrons emitted from cathode 22 along beam axis 26 and prevents them from striking electrode 96. The blocking of electron flow by center tab 158 prevents unnecessary heating of electrode 96, which would cause aperture misalignment with adjacent electrodes 94 and 98, or secondary electron emission from electrode 96. Aside from the heating, the impact of electrons on electrode 96 could also cause secondary electron emission.

Slots 140, 142, 146, and 150 define straight lines, and slots 144, 148, 152, and 154 define dogleg profiles. The reason for the dogleg profiles is that lower cylinder 92 has eight slots 160 (Fig. 3--only two shown in phantom) positioned in equally spaced angular intervals around its periphery. The regions between adjacent slots 160 in lower cylinder 92 provide individual support surfaces for the wedge segments. The slots cut between adjacent apertures near the center of control grid electrode 94 do not, however, define wedge segments of equal angular extent because the aperture array does not define a true circle. As was stated above, an aperture array geometry of this character was required to create the horizontally and vertically uniform pixel spacing on display surface 28. The dogleg profiles of slots 144, 148, 152, and 154 facilitate, therefore, the formation of wedge segments of a size that align with the support surfaces of lower cylinder 92.

Since the wedge segments are electrically isolated from one another, the number of electrons propagating through any one of them can be separately controlled. This is accomplished by applying a voltage on the conductive tab of the desired wedge segment. Each one of the wedge segments of control grid 94 is biased at a negative potential relative to cathode 22, which is at ground potential, to provide a standard triode operation. Each one of electrodes 96, 98, 100, and 46, receives an applied voltage that is common to the apertures in it. Electrode 96 is used to adjust the electron beam cutoff voltage. The lowest cutoff voltage of any segment of control grid electrode 94 is - 20 volts. To accomplish this, a voltage of between 100 volts and 300 volts is applied to electrode 96. Electrode 98 cooperates in collimating and converging the electron beams. The voltage applied to electrode 98 controls the divergence of each of the electron beams and thereby affects the brightness of the resulting image. The voltage applied to electrode 98 typically ranges from 50 volts to 300 volts. Varying the voltage on electrode 98 from 300 volts to 50 volts varies the brightness of the image on display surface 28 from minimum brightness to maximum brightness, respectively. The voltage applied to electrode 98 is more negative relative to that applied to electrode 96.

Electrode 100 provides the outer boundary of a collimation lens that is formed by electrodes 96, 98, and 100. For reasons that will be given below, the same potential of approximately 300 volts is applied to both electrodes 100 and 46. The distance between electrodes 100 and 46 defines, therefore, an electric field-free region that dictates the allowable divergence of each of the electron beams as they exit grid electrode structure 24.

Fig. 5 shows convergence electrode structure 10 and drift tube section 34, which are positioned downstream and receive the parallel electron beams emerging from grid electrode structure 24. Drift tube section 34 includes spaced-apart tubular drift electrodes 170 and 172. Convergence electrode structure 10 and drift electrodes 170 and 172 are of cylindrical shape and have their axes coincident to beam axis 26. Convergence cylinder 10 converges the bundle of eight electron beams toward beam axis 26 as they propagate through limiting aperture electrode 36. Convergence is necessary because of the generally circular, off-axis pixel array geometry defined by the apertures in electrodes 94, 96, 98, 100, and 46 of grid electrode structure 24. In the absence of compensation of some type, this array geometry would cause a substantial number of the electrons in each beam to strike the periphery of the aperture 174 of limiting aperture electrode 36.

A preferred form of compensation entails positioning convergence cylinder 10 immediately adjacent and downstream of exit electrode 46 and biasing convergence cylinder 10 negative relative to electrode 46 and drift cylinders 170 and 172. The resulting electric field developed within convergence cylinder 10 can be characterized by equipotential surfaces that develop force lines which direct the eight beams toward beam axis 26. As a consequence, a substantial number of the electrons in the eight beams shift their propagation directions and pass through aperture 174 of limiting aperture electrode 36. Passing a substantial number of the electrons through limiting aperture electrode 36 results in a reduction in beam current loss and thereby provides a brighter display.

In a preferred embodiment, a potential difference of between 200 volts and 250 volts is applied to convergence cylinder 10, and a potential difference of about 300 volts is applied to drift cylinders 170 and 172, which are electrically connected to electrodes 46 and 100 of grid electrode structure 24. The magnitude of the potential differences applied to, and the combined length of, convergence cylinder 10 and drift tube section 34 affect the magnification of the image. The combined length 176 of convergence cylinder 10 and drift tube section 34 is about 76.962 mm. Convergence cylinder 10 and drift cylinders 170 and 172 are of length 178 of 7.239 mm, length 180 of 24.765 mm, and length 182 of 40.894 mm, respectively. Convergence cylinder 10 is spaced apart from electrode 46 by a distance 184 of 1.27 mm and from drift cylinder 170 by a distance 186 of 1.27 mm. Drift cylinders 170 and 172 are separated by a distance 188 of 0.635 mm. Convergence cylinder 10 and drift cylinders 170 and 172 have inner diameters 190 of about 12.7 mm, and the circular aperture 174 in limiting aperture electrode 36 has a diameter 192 of 3.175 mm. Four glass mounting rods 193 (only two shown) provide the support for the components contained in neck 18.

Fig. 6 is an illustration showing the beam-to-beam compression phenomenon that results from an increase in beam current by raising the voltage on a wedge segment of control grid electrode 94. Fig. 6 shows the beam-to-beam compression as a function of changes in brightness that occur as the beams are scanned to form the horizontal lines 194, 196, 198, 200, 202, 204, 206, and 208 in an operational cathode-ray tube. The application of a relatively low voltage to cylinders 170 and 172 causes beam-to-beam compression regions 210, 212, 214, 216, 218, 220, 222, and 224 to develop in a multiple beam cathode-ray tube as the beam current and display brightness increases. It is believed that the presence of space charge is responsible for this phenomenon.

With reference to Fig. 5, compression electrode structure 12 overcomesthis problem and comprises an immersion lens cylinder that is positioned downstream of, and is electrically connected to, drift cylinders 170 and 172. Immersion lens cylinder 12 is axially aligned with beam axis 26. One end of immersion lens cylinder 226 extends into helix coil 38 and is electrically connected to the winding thereof which provides a potential difference of about 300 volts. In a preferred embodiment, the appropriate winding is about 6.35 mm from the entrance end of helix coil 38.

The use of immersion lens cylinder 12 to reduce beam-to-beam compression may be best explained by comparison with a cathode-ray tube that does not use it. In a cathode-ray tube that does not use immersion lens cylinder 12, the electric field present at the entrance end of helix coil 38 is configured such that the electron beams converge to form the second array of crossovers in plane 48, which is about 2.54 cm inside helix coil 38 at its entrance end. Positioning the second array of crossovers at plane 48 in a cathode-ray tube with immersion lens cylinder 12 absent requires that the drift cylinder 172 be electrically connected to a winding of helix coil 38 that provides a potential difference of about 225 volts. Biasing drift cylinders 170 and 172 at the relatively low potential difference of 225 volts is desirable to operate successfully the neck magnetic coils but exacerbates beam-to-beam compression as the beam current increases to enhance image brightness.

Positioning immersion lens cylinder 12 at the exit end of drift cylinder 172 and a short distance into the helix accelerating field increases to 300 volts the potential difference applied to immersion lens cylinder 12 and drift cylinders 170 and 172, which are electrically common to it. This increase in potential difference has been found to be sufficient to provide an acceptable compromise between the function of the neck magnetics and the amount of beam-to-beam compression as the image brightness level increases. The second array of crossovers is formed substantially at plane 48 within helix coil 38, thereby producing the same screen resolution without a noticeable increase in beam or array distortion.

It is believed that the increase in voltage applied to drift cylinders 170 and 172 allows less time for adjacent beam interaction that stems from space charge phenomenon. The result is an array of electron beams with increased brightness but without noticeable beam-to-beam compression.

In a preferred embodiment, immersion lens cylinder 12 is comprised of two cylinder portions 228 and 230 of different diameters. Cylinder portion 228 has an inner diameter 190 of 12.7 mm and a length 232 of 7.62 mm. Cylinder portion 230 has an inner diameter 234 of 2.921 cm and is of sufficient length to extend about 6.35 mm into helix coil 38 at its entrance end. Cylinder portion 228 is spaced apart from aperture limiting electrode 36 by a distance 236 of 0.889 mm.

It will be obvious to those having skill in the art that many changes may be made in the above-described details of the preferred embodiment of the present invention. The scope of the present invention should, therefore, be determined only by the following claims.

CLAIMS

1. A multiple beam electron discharge tube, comprising:

beam-producing means for producing plural beams of electrons directed along a beam axis in the tube toward a display screen positioned at one end of the tube;

deflection means for deflecting the electron beams relative to the beam axis to produce an image on the display screen;

convergence means positioned between the beam-producing means and the deflection means for converging the electron beams, the convergence means including a first electrode structure that is electrically isolated from and positioned upstream of a second electrode structure that has a limiting aperture through which the electron beams propagate; and

first biasing means for providing between the first and second electrode structures a first potential difference of an amount that directs through the limiting aperture a substantial number of the electrons in each one of the beams.

2. The tube of claim 1 which further comprises a grid electrode structure that includes an exit element from which the electron beams emerge in generally parallel relation and in a generally circular, off-axis array around the beam axis, and in which the first and second electrode structures comprise respective first and second tubular members through which the electron beams propagate.

3. The tube of claim 2 which further comprises second biasing means for providing a second potential difference between the exit element and the first electrode structure, and in which the limiting aperture has a center that is aligned with the beam axis, the first potential difference being such that the first tubular member is biased negative relative to the second tubular member and the second potential difference being such that the first tubular is biased negative relative to the

element, thereby to shift the propagation directions of the electron beams toward the center of the limiting aperture.

4. The tube of claim 3 in which the first potential difference equals the second potential difference.

5. The tube of claim 2 in which each of the first and second tubular members is of cylindrical shape.

6. The tube of claim 2 in which the exit element has a planar surface that includes a pattern of apertures, and a different one of the electron beams propagates through each one of the apertures.

7. The tube of claim 1 in which the deflection means comprises a deflection yoke assembly that produces a magnetic field to deflect the electron beams.

8. In a multiple beam electron discharge tube having beam-producing means that produces plural electron beams directed along a beam axis and deflection means for deflecting the electron beams to form an image on a display screen, the improvement comprising:

convergence means positioned between the beam-producing means and the deflection means and having a first voltage applied thereto to converge the electron beams and pass them through a limiting aperture electrode;

beam accelerating means for increasing the propagation velocity of the beam electrons beams toward the screen; and

beam-to-beam compression compensating means positioned between the convergence means and the beam accelerating means, the beam accelerating means delivering to the convergence means a second voltage that is positive relative to the first voltage and is of an amount that prevents beam-to-beam compression as the image brightness increases.

9. The tube of claim 8 in which the beam accelerating means comprises a helix coil having an entrance end and the compression compensating means comprises a tubular electrode having an exit end that extends into the entrance end of the helix coil, the

tubular electrode being electrically connected to a winding of the helix to receive the second voltage.

10. The tube of claim 8 which further comprises a tubular drift tube section that is positioned between the convergence means and the compression compensating means, and in which the compression compensating means comprises a tubular electrode, the tubular electrode being coaxially aligned with an electrically common to the drift tube section.

11. The tube of claim 8 in which the limiting aperture electrode is electrically common to the compression compensating means.

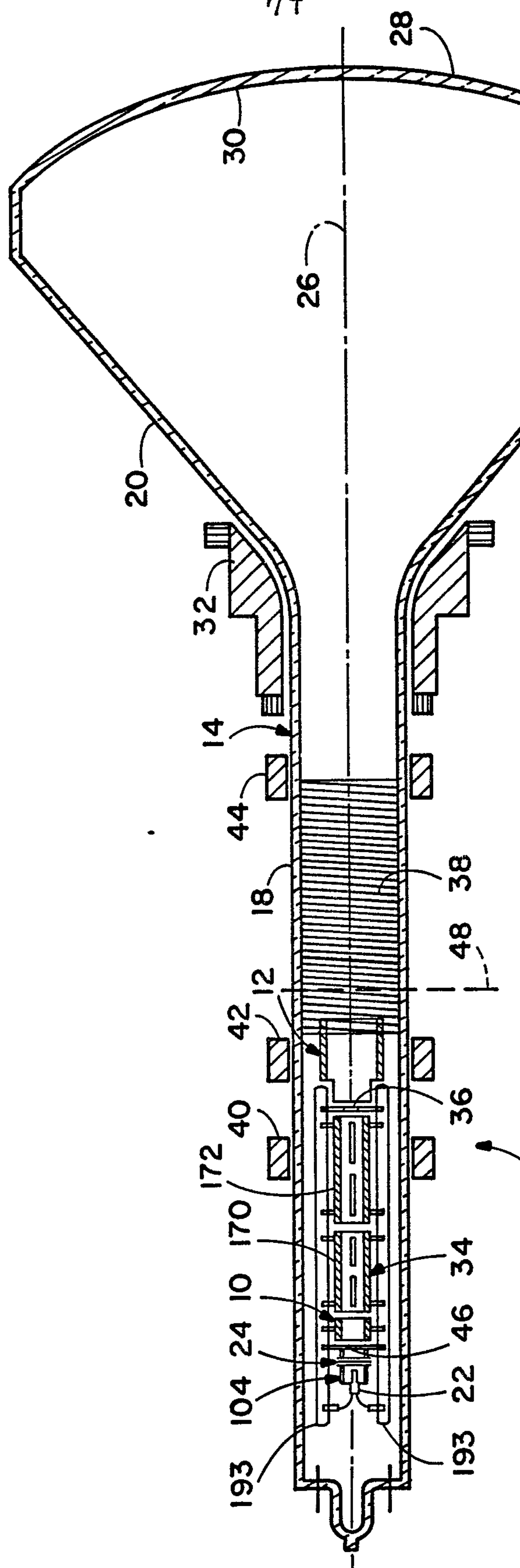


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FIG. 1

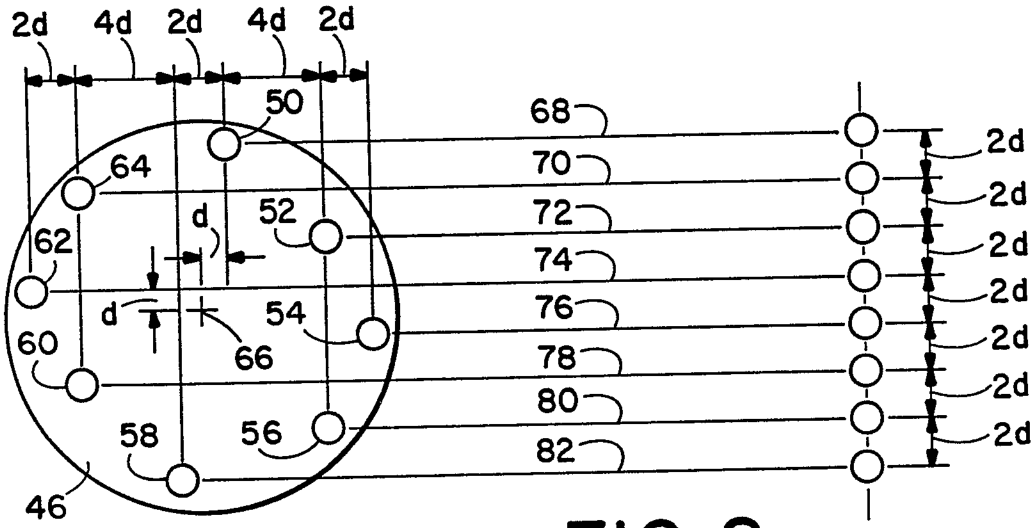
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FIG. 2

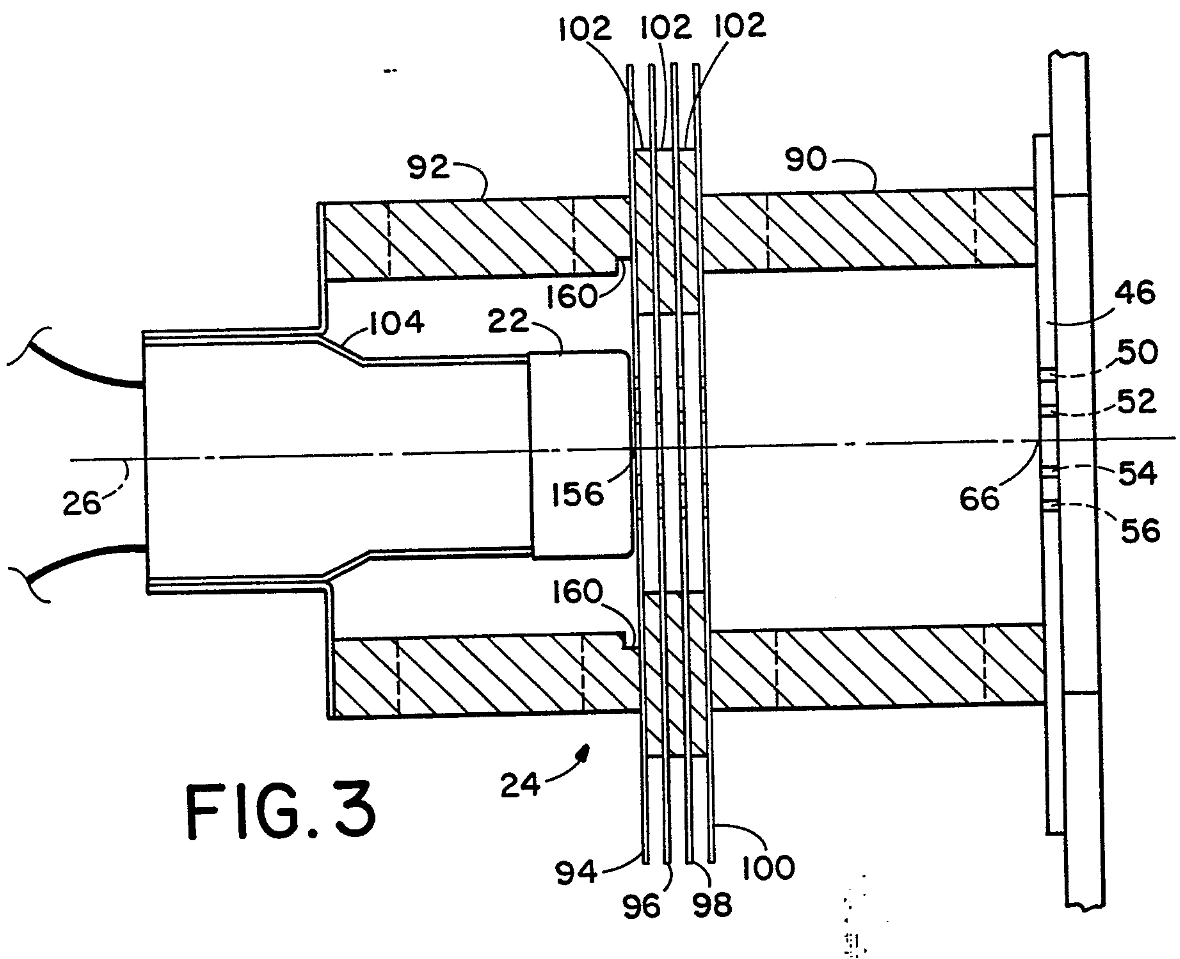
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FIG. 3

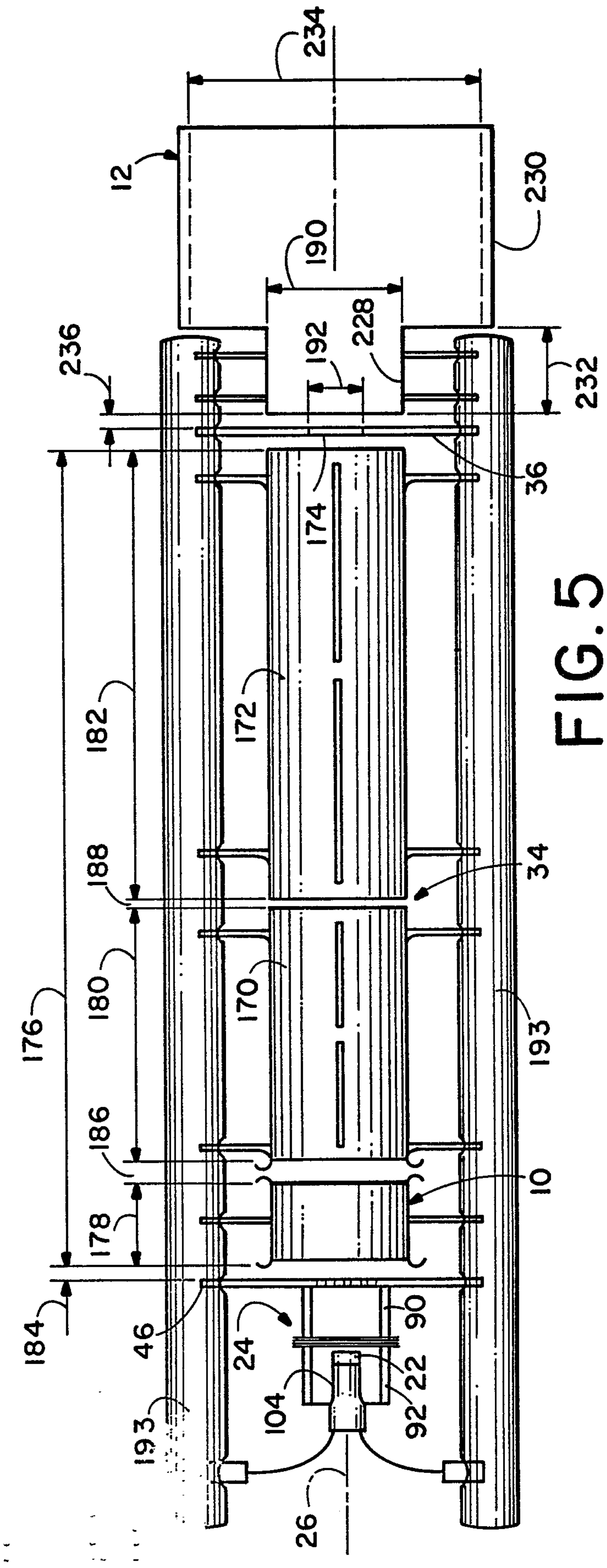
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FIG. 5

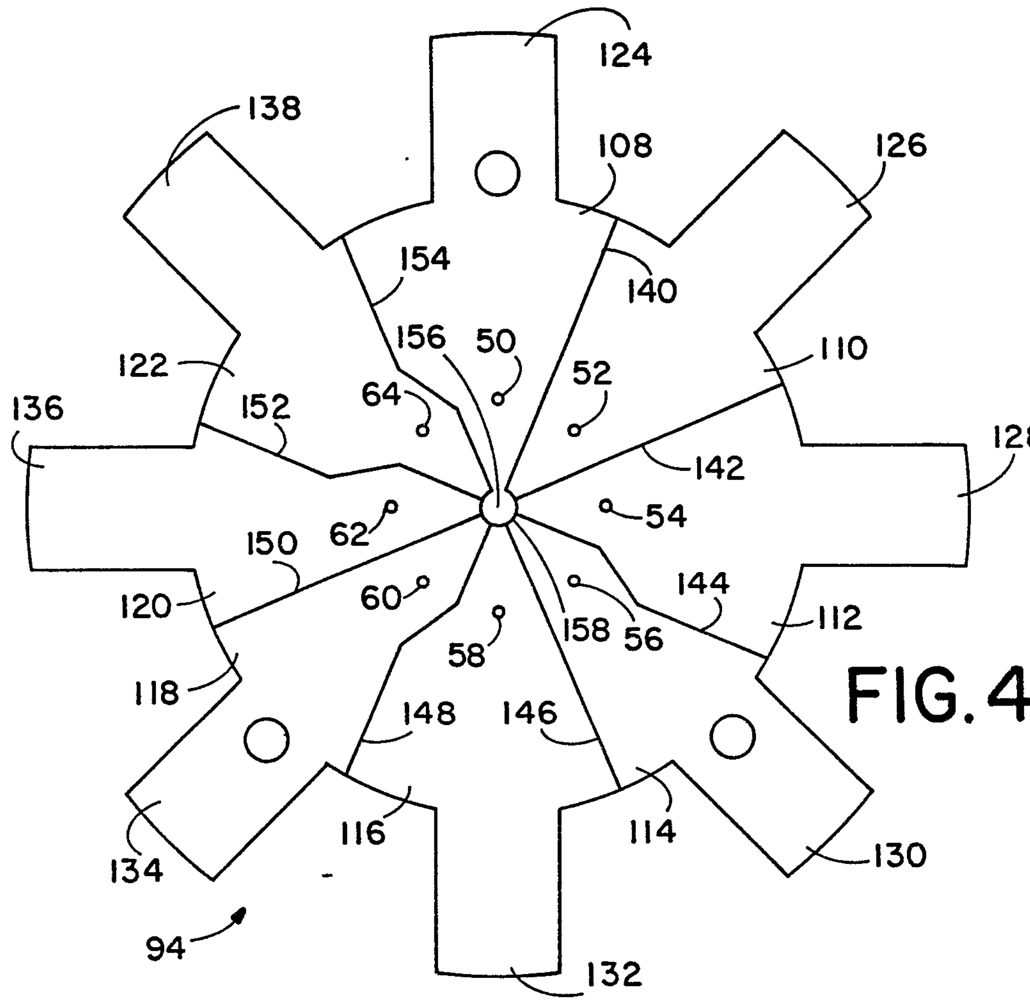

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FIG. 4

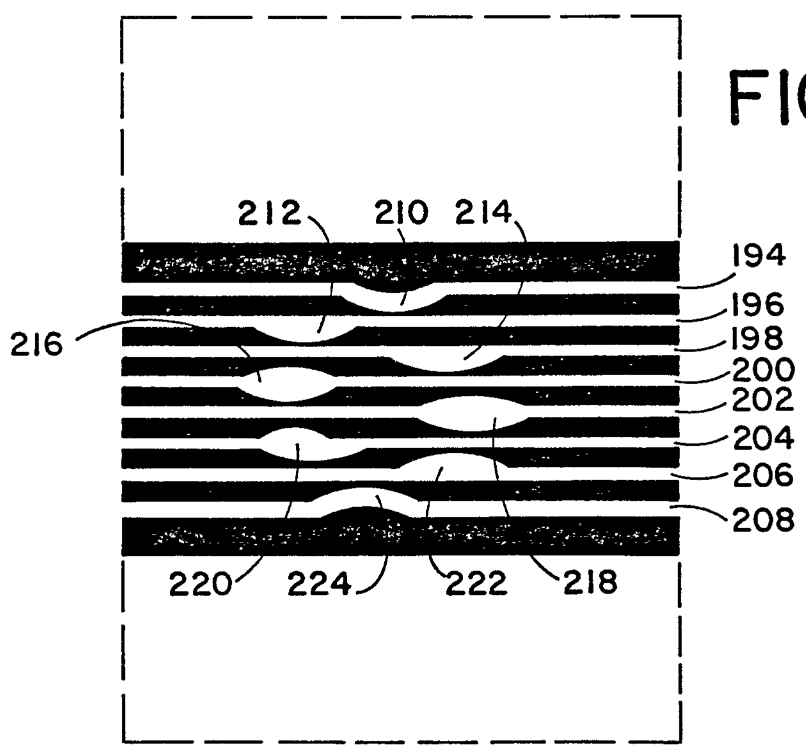

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FIG. 6