June 15, 1954 R. B. GETHMANN 2,681,421

MAGNETIC FOCUSING STRUCTURE FOR ELECTRON BEAMS

Filed March 4, 1952

Fig.1.

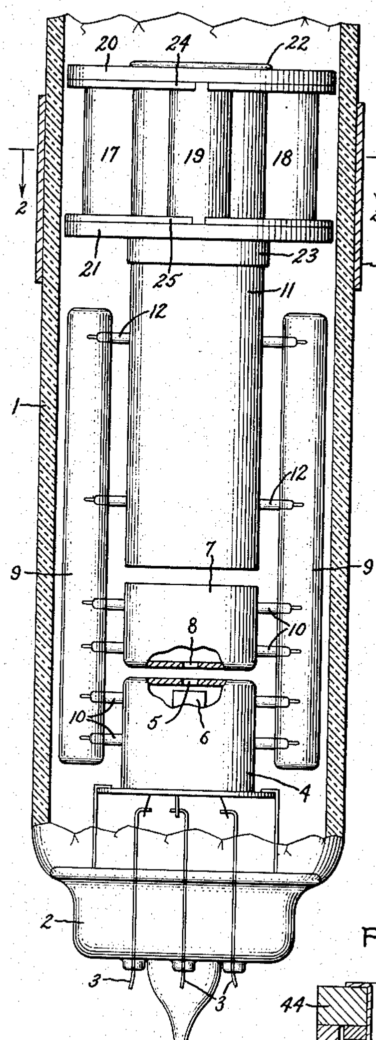


Fig.3.

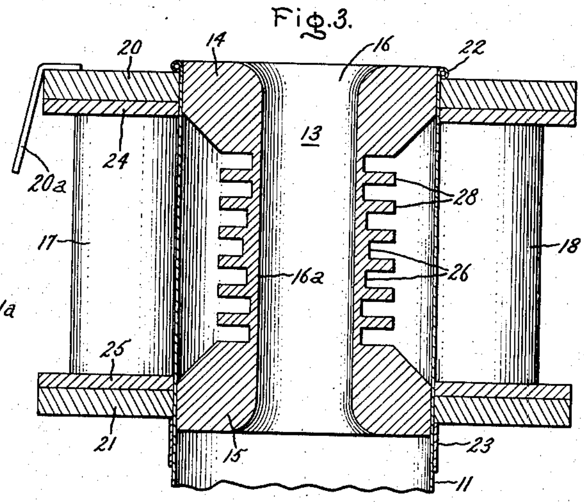


Fig.4.

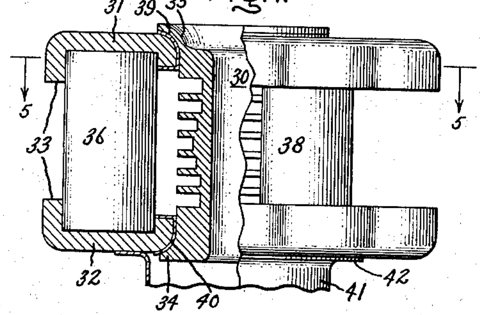


Fig.5.

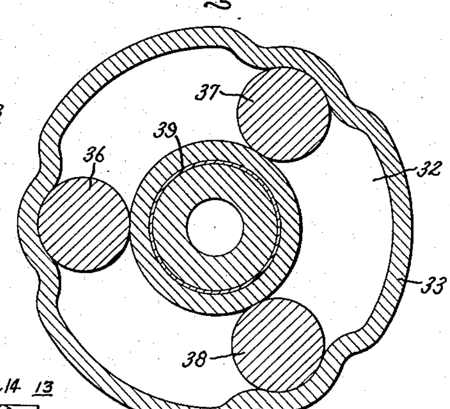


Fig.6.

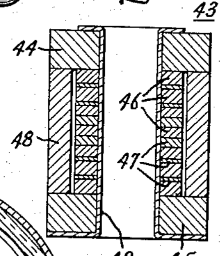
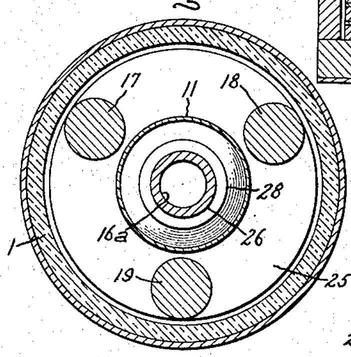


Fig.2.



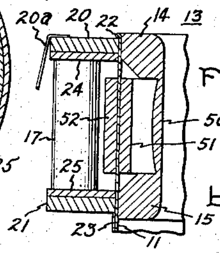


Fig.7.

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MAGNETIC FOCUSING STRUCTURE FOR ELECTRON BEAMS

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12 Claims. (Cl. 313—84)

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My invention relates to improved magnetic focusing structures for cathode ray tubes and particularly to such structures employing permanent magnets as a source of magnetomotive force.

In cathode ray tubes of the type presently in large scale production, focusing of the beam is accomplished by means of a focusing coil positioned exteriorly on the neck of the cathode ray tube. This device is rather bulky, expensive and requires a large amount of magnetic material. Some attempts have been made in the prior art to accomplish the focusing by means of a magnetic structure supported within the cathode ray tube envelope. These prior art structures have not found commercial use and have not provided the quality of focusing necessary for use in tubes for television receivers, for example.

The present invention is directed to an improved internal focusing structure, particularly one employing permanent magnets, which provides a symmetrical focusing field about the axis of the focusing structure, and which also provides for a controlled predetermined distribution of the magnetomotive force along the axis of the focusing structure to provide focusing which is substantially free of spherical aberration, or in many cases which provides a predetermined amount of aberration of the proper sign to compensate for aberration introduced into the focusing by other components of the electron gun structure of the tube. Accordingly, it is an important object of my invention to provide a new and improved internal magnetic focusing structure for cathode ray tubes which provides focusing of the beam without distortion of the beam cross section and without introducing unwanted spherical aberration.

It is another object of my invention to provide a simplified internal focusing structure which employs a small volume of metal within the tube, which is simple and inexpensive to manufacture and which is readily adjustable to provide variation in the intensity of the focusing field.

Further objects and advantages of my invention will become apparent as the following description proceeds, reference being had to the accompanying drawing and its scope will be pointed out in the appended claims. In the drawing, Fig. 1 illustrates an electron gun for a cathode ray tube incorporating a magnetic focusing structure embodying my invention. Fig. 2 is a sectional view taken along the line 2—2 of Fig. 1. Fig. 3 is an enlarged elevational view in section of the magnetic focusing structure of Fig. 1.

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Fig. 4 is an elevational view partially in section of a modified magnetic focusing structure embodying my invention, Fig. 5 is a sectional view taken along the line 5—5 of Fig. 4, Fig. 6 is an elevational view in section of a further modification of my invention and Fig. 7 is an elevational view in section and partially broken away of still a further modification of my invention.

Referring now to Fig. 1, I have shown my invention embodied in a cathode ray tube gun structure supported within the neck 1 of a cathode ray tube envelope including a stem member 2 from which the gun is supported and through which the lead-in conductors 3 are sealed. In accordance with usual practice, these lead-in conductors provide externally accessible connections to the various elements of the gun and also support the gun structure within the envelope. The gun illustrated is of the tetrode type and includes a grid member 4 formed as an inverted cup having an aperture 5 through which electrons pass. The electrons are supplied by a suitable cathode 6 supported within the grid cylinder with the emitting surface adjacent the grid aperture in a manner well understood by those skilled in the art. A second or accelerating grid 7 of cup shape and having a beam aperture 8 is supported in inverted relation with respect to the grid cylinder 4 by means of a plurality of glass stalks 9 secured to the grid cylinders 4 and 7 by means of radially extending pins 10. The gun structure also includes a cylindrical second grid or anode member 11 supported in axially spaced relation with respect to the accelerating grid 7 by radially extending pins 12.

The magnetic focusing structure of the embodiment illustrated in Figs. 1 and 3 is supported directly from the final anode cylinder 11 which is made of stainless steel or other essentially nonmagnetic material. The magnetic lens member is in the form of a machined cylinder 13 secured within the anode cylinder 11. As illustrated clearly in Fig. 3, cylinder 11 includes pole pieces 14 and 15 provided by annular end portions which end portions just fit the inner diameter of the final anode 11, and which may be secured in position by welding to the anode sleeve. The focusing member 13 is apertured as shown at 16 to provide a passage for the electron beam in which the focusing takes place. The member 13 is constructed in a novel manner to provide the desired distribution of magnetomotive force within the focusing region defined by the passage 16 as will be described in detail at a latter point in the specification. The magnetomotive force is supplied by three cylindrical permanent magnets 17, 18 and 19 supported in circumferentially spaced relation around the exterior of the anode cylinder 11 and retained in position by a pair of soft iron washers 20 and 21 which are secured against axial movement by a rolled edge 22 on the upper or outer end of the anode cylinder 11 and by a sleeve 23 which is spot welded to the exterior of the anode cylinder 11. The magnets are retained in position by a pair of retaining washers 24 and 25 having suitable openings for receiving the ends of the permanent magnets and welded or otherwise secured to the opposed faces of the soft iron washers 20 and 21. The openings in the washers 20 and 21 are dimensioned to receiving the exterior of the anode 11 and to provide effectively a continuation of the pole pieces provided by the enlarged ends 14 and 15 of the focusing member 13. The gap in the magnetic material provided by the relatively low permeability stainless steel of the anode sleeve assists in the even distribution of a flux produced by the three magnets and provides a circumferential distribution which is essentially as good as could be obtained with an axially magnetized cylinder of permanent magnet material which is as a matter of economics much more expensive to produce.

For the purpose of adjusting the strength of the focusing flux produced within the member 13 I provide an external shunt in the form of a cylinder 21*a* of magnetic material which may be adjusted in axial position to tube envelope to determine the reluctance of the shunt path between washers 20 and 21 provided by the washer 21*a* and the two air gaps.

As will be readily understood by those skilled in the art the final anode is usually operated at the same voltage as the wall coating of the bulb and for the purpose of making electrical contact with such a coating (not shown) a plurality of circumferentially spaced spring tabs 20*a* are secured to the end washer 20 of the anode and focusing assembly.

In accordance with an important aspect of the present invention, the quality of the focusing obtained is greatly improved as compared with prior art focusing arrangements. The improvement results from a number of structural features which, though usable individually, are combined in a relatively simple structure.

In accordance with one feature of the present invention, the passage 16 through which the beam passes is defined by a continuous wall 16*a*, as distinguished from a focusing gap. The wall is of such cross section that the magnetomotive force impressed across the ends thereof by magnets 17, 18 and 19, saturates the wall section and provides substantial focusing flux within the passage 16. The length of the saturating section is also preferably in the order of three or more times the radius of the focusing passage. Both of these features assist in providing a focusing field which is more uniform, and generally parallel to the axis of the focusing passage.

The term saturated as used here does not mean complete saturation with the resultant reduction in permeability of the saturated section to unity but rather a saturation sufficient to reduce the permeability to a value clearly below that associated with unsaturated magnetic materials. This means that the degree of saturation may be controlled by varying the cross section of the lens wall and in this way to obtain a non-uniform distribution of magnetomotive force along the surface of the lens structure in an axial direction. In the embodiment illustrated in Fig. 3, this non-uniform thickness of the saturated wall section is obtained by machining into the member 13 a plurality of circumferential recesses 26 which extend into the member different radial distances. In the particular construction shown, the wall thickness increases toward the central portion of the lens member (measured along the longitudinal axis of the lens). This particular variation in cross section of the lens tends to provide a lens having negative spherical aberration and by proper control of the amount of this aberration it can be made to just compensate for the aberration of the electrostatic lens existing in the gun structure and including, for example the lens provided by cylinders 7 and 11 which are normally operated at different voltages.

When the saturable wall section is formed in this manner, the radial extending ribs or fins 28 provide a path for leakage flux from the magnets 17, 18 and 19 which does not affect the focusing action of the lens and which has a relatively low reluctance circumferentially and a relatively high reluctance in a longitudinal direction. If the recesses are as deep or deeper than their axial width then the shielding accomplished by them is essentially complete and the localized leakage flux from the individual magnets does not disturb the uniformity of the focusing field.

The non-magnetic gaps interposed between the pole pieces 14 and 15 and the washers 20 and 21 respectively and provided by the anode cylinder 11 in Fig. 3 assist materially in obtaining a uniform distribution of magnetomotive force across the entire circumference of the pole pieces 14 and 15. This combination of the non-magnetic gaps and the shielding provided by the ribs 28 render the action of the individual magnets essentially as effective as a perfectly magnetized cylinder of permanent magnet material. This is a substantial advantage, since it is very difficult to obtain a perfectly magnetized cylinder of permanent magnet material and in addition such a structure is rather expensive.

In Figs. 4 and 5, I have shown a modified form of my invention which is in some respects easier to assemble. The focusing member 30 is in general similar to the member 13 as shown in Fig. 3 but is differently shaped at the ends in order to facilitate assembly with a pair of washers 31 and 32 having circular flanges 33 at the outer edges thereof and directed toward one another. The member 30 is formed with a flared portion 34 providing a shoulder on which the washer 32 may rest, and at the other end with a section 35 of reduced cross section which may be spun out over the upper surface of the washer 31 during assembly to clamp the washer 31 and 32 and the three permanent magnet members 36, 37 and 38 together. As illustrated in Fig. 4, a suitable non-magnetic gap between washers 31 and 32 and the parts 34 and 35 focusing member 30 is provided by interposed washers 39 and 40 of suitable non-magnetic material such as stainless steel. The washers 31 and 32 and the parts 34 and 35 of focusing member 30 combine to provide the pole pieces of the focusing structure. As apparent from an inspection of Figs. 4 and 5, the flanges 33 of the washers 31 and 32 are shaped to retain the permanent magnets in circumferential position. The assembly including the focusing member 30, the washers 31 and 32 and the permanent magnet members 36, 37 and 38 is secured on the outer end of a second anode cylinder 41. For the purpose of this connection, the cylinder is provided with an outwardly extending circumferential flange 42 which is welded or brazed to the face of the washer 32. It will be appreciated that the structure just described operates in the same manner as the one described in connection with Figs. 1, 2 and 3, and may provide a more economical structure from a manufacturing point of view.

In Fig. 6, I have shown a still further modification of my invention in which the lens structure 43 corresponds generally to the lens member 13 of Fig. 3. The lens structure instead of utilizing a saturable wall section utilizes a stack of washers which are alternately of magnetic and substantially non-magnetic material. Referring now to Fig. 6, the assembly includes an annular stack including soft iron pole pieces 44 and 45 separated by a plurality of washers 46 of non-magnetic material such as stainless steel with interposed washers 47 of high permeability iron. The washers 46 and 47 are substantially smaller outer diameter than the pole pieces 44 and 45 leaving room to accommodate annular cylindrical permanent magnet 48 between the pole pieces 44 and 45. The assembly may be secured together in any suitable manner and attached to the end of the final anode, if desired. For example, the assembly may be clamped together by a stainless steel eyelet illustrated at 49.

It will be noted that in the modification in Fig. 6 that the washers of stainless steel provide a path of relatively low permeance and the iron washers provide a path of relatively high permeance. Since the washers of low permeability are made progressively thinner toward the center of the stack and the washers of high permeability are made progressively thicker toward the center, it is apparent that the magnetic potential gradient is along the wall defining the beam passage decreases toward the longitudinal center of the lens while the magnetic potential gradient is substantially constant along the axis. This is the same type of disturbance as was obtained by the saturable wall of the lens of Fig. 3 where the wall section is of greater thickness near the longitudinal center of the lens.

In Fig. 7, I have shown a still further modification to my invention which corresponds generally to the modification shown in Fig. 3 and corresponding parts have been designated by the same reference numerals. In the construction shown in Fig. 7, the lens member 13 includes annular pole pieces 14 and 15 and a generally cylindrical wall portion 50 extending between the pole pieces and having a varying cross section along its length to provide the desired distribution of magnetomotive along the focusing passage. The modification of Fig. 7 differs from that shown in Fig. 3 primarily in the arrangement provided for obtaining a low reluctance path in a circumferential direction without effectively short circuiting the focusing passage in an axial or longitudinal direction. In this modification, this path is provided by a pair of annular or ring like members 51 and 52 of low reluctance material, such as soft iron, interposed between the magnets 17, 18 and 19 and the focusing cylinder. These rings may to advantage be supported from opposite sides of the non-magnetic cylinder provided by the stainless steel anode cylinder 11 which provides a non-magnetic gap therebetween. It is appreciated that the rings 51 and 52 are spaced at their ends from the pole pieces 14 and 15 so as to provide a high reluctance path in a longitudinal direction. These ring members prevent the localized magnetomotive force of the three magnets from disturbing the uniformity of the focusing field in a plane transverse to the axis of the focusing cylinder.

In the foregoing description, a number of modifications embodying my invention have been described. It will be appreciated that in its broader aspects, the invention involves the utilization of a physical structure between the pole pieces of a magnetic lens which presents a relatively low magnetic permeability as compared with unsaturated iron and which more specifically provides a non-uniform and predetermined permeability along its length to give a spherical aberration free lens or a lens having a predetermined amount of special aberration to compensate for spherical aberration of any other lens which acts on the beam being focused. It has been found that for a spherical aberration free lens the area under the curve of magnetomotive force versus axial distance along the lens should be approximately equal for both the axis of the lens and the inner surface of the lens wall. As is readily apparent from the foregoing description, these areas can be made the same or different by a predetermined amount by suitable dimensioning of the interposed wall space defining the beam passage.

While I have shown my invention applied to a straight electron gun, that is a gun having no ion trap, it will be apparent that it may be used with such guns with all of the advantages of controlled correction of aberration that have been described in connection with the illustrated embodiment.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A magnetic focusing structure for an electron beam comprising a generally cylindrical lens of magnetic material having a passage therethrough, said lens including a generally annular pole piece at each end thereof and an intermediate hollow cylindrical section having a varying cross section along its length, and means surrounding said lens member and impressing a magnetizing force across said pole pieces of a strength to produce saturation of said cylindrical section to produce a non-uniform magnetic potential gradient along the length of the inner surface of said hollow cylindrical section.

2. A magnetic focusing structure for an electron beam comprising a generally cylindrical lens member of magnetic material having a passage therethrough, said member including a generally annular pole piece at each end thereof and an intermediate hollow cylindrical section having a varying cross section along its length to produce a non-uniform magnetic potential gradient along the length of the inner surface of said hollow cylindrical section when a magnetomotive force of sufficient strength to saturate said hollow cylindrical section is impressed across said pole pieces.

3. A magnetic focusing structure for an electron beam comprising a generally cylindrical lens member of magnetic material having a passage therethrough, said member including a generally annular pole piece at each end thereof and an intermediate hollow cylindrical section having a cross section substantially less than the cross section of said pole pieces, and means surround-

ing said lens member and impressing a magnetizing force across said pole pieces of a strength to produce saturation of said intermediate hollow cylindrical section.

4. A magnetic focusing structure for an electron beam comprising a generally cylindrical lens member of magnetic material having a focusing passage therethrough, said member including a generally annular pole piece at each end thereof and an intermediate hollow cylindrical section, a plurality of radially extending ribs of magnetic material on the exterior of said cylindrical section and a plurality of circumferentially spaced permanent magnet members positioned outside of said cylindrical section for impressing a magnetizing force across said pole pieces.

5. A magnetic focusing structure for an electron beam comprising a generally cylindrical lens member of magnetic material having a passage therethrough, said member including a generally annular pole piece at each end thereof and an intermediate hollow cylindrical section, a ring of magnetic material surrounding each of said pole pieces, non-magnetic means interposed between the respective rings and pole pieces, a plurality of elongated permanent magnets extending between said rings and for impressing a magnetizing force across said pole pieces.

6. A magnetic focusing structure for an electron beam comprising a generally cylindrical lens member of magnetic material having a passage therethrough, said member including a generally annular pole piece at each end thereof and an intermediate hollow cylindrical section, a ring of magnetic material surrounding each of said pole pieces, non-magnetic means interposed between the respective rings and pole pieces, a plurality of elongated permanent magnets extending between said rings and for impressing a magnetizing force across said pole pieces, said hollow cylindrical section having a plurality of longitudinally spaced outwardly extending ribs of magnetic material providing leakage paths for flux produced by said permanent magnets.

7. A magnetic focusing structure for an electron beam comprising a generally cylindrical lens member of magnetic material having a cylindrical passage therethrough, said member including a generally annular pole piece at each end thereof and an intermediate hollow cylindrical section having a cross section substantially less than the cross section of said pole pieces, the length of said cylindrical section being in excess of three times the radius of said passage and means surrounding said lens member and impressing a magnetizing force across said pole pieces of a strength to produce saturation of said intermediate hollow cylindrical section.

8. A magnetic focusing structure for an electron beam comprising a generally cylindrical lens member of magnetic material having a cylindrical focusing passage therethrough, said member including a generally annular pole piece at each end thereof and an intermediate hollow cylindrical section having a predetermined non-uniform permeance along its length to produce a non-uniform magnetic potential gradient along the inner surface of said hollow cylindrical section when a magnetomotive force is impressed across said pole pieces.

9. A magnetic focusing structure for an electron beam comprising a generally cylindrical lens having a focusing passage therethrough, said lens including a generally annular pole piece of high permeance at each end thereof and an intermediate hollow cylindrical section including a stack of alternately high and low permeance rings of differing thicknesses to produce a non-uniform distribution along the length of the inner surface of said cylindrical section when a magnetomotive force is impressed across said pole pieces.

10. In combination, an electron gun for producing a beam of electrons and including a cylindrical anode, a magnetic focusing lens supported from said anode and having a cylindrical passage therethrough in alignment with the axis of said anode, said focusing lens including a pair of annular pole pieces and a relatively thin walled generally cylindrical portion interposed between said pole pieces and means impressing a magnetomotive force across said pole pieces of a magnitude to produce substantial saturation of said wall portion.

11. A magnetic focusing structure for an electron beam comprising a focusing lens having a cylindrical passage therethrough in alignment, said focusing lens including a pair of annular pole pieces and a relatively thin walled generally cylindrical portion interposed between said pole pieces, individual magnets supported in spaced circumferential relation and said lens and impressing a magnetomotive force across said pole pieces of a magnitude to produce substantial saturation of said thin walled portion and means interposed between said magnets and said thin walled portion providing a low reluctance circumferential path around said thin walled section and a high reluctance path between said pole pieces.

12. In combination, an electron gun for producing a beam of electrons and including a cylindrical anode of non-magnetic material, a magnetic lens within said anode member including a pair of annular pole pieces having an outer surface conforming in size and shape to the interior surface of said anode, a pair of annular washers of magnetic material surrounding said anode and located opposite said pole pieces in an axial direction, and permanent magnet means positioned on the outside of said anode and extending between said washers.

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