April 26, 1960 T. M. SHRADER 2,934,666

ELECTRON GUN

Filed Dec. 31, 1956 2 Sheets-Sheet 1

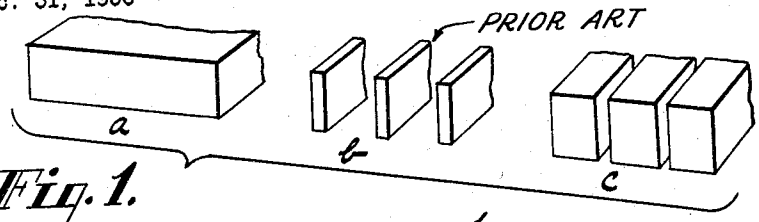


Fig. 1.

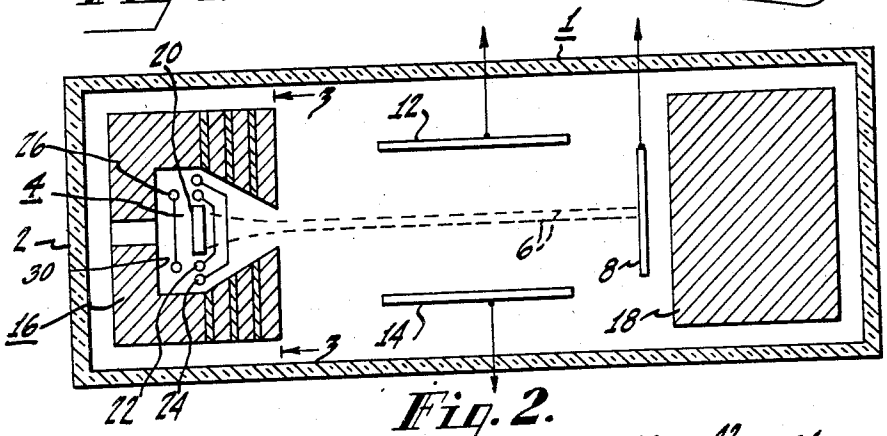


Fig. 2.

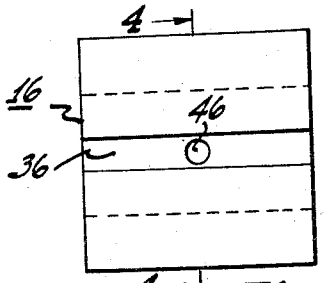


Fig. 3.

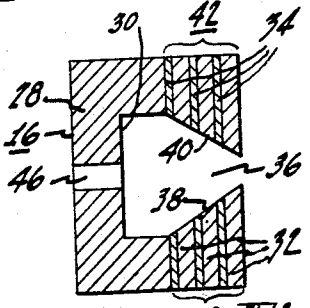


Fig. 4.

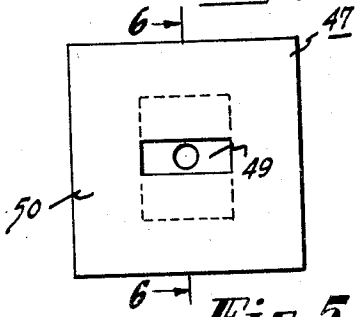


Fig. 5.

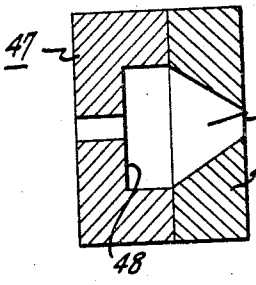


Fig. 6.

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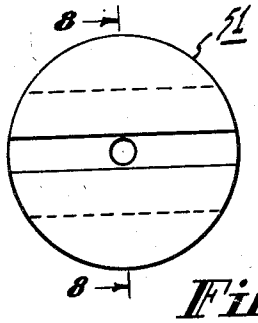


Fig. 7.

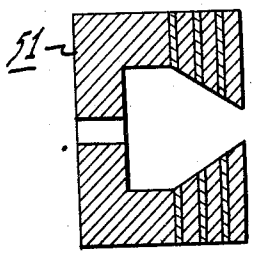


Fig. 8.

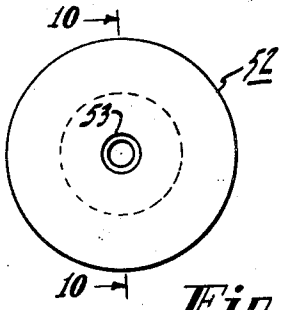


Fig. 9.

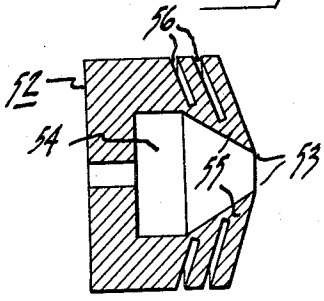


Fig. 10.

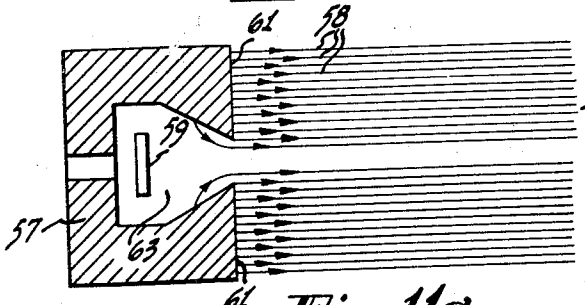


Fig. 11a.

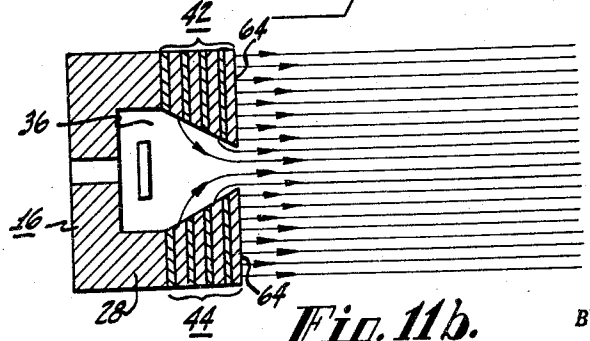


Fig. 11b.

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ELECTRON GUN

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Application December 31, 1956, Serial No. 632,622

7 Claims. (Cl. 313—84)

This invention relates to the production of a uniform cross section, high current electron beam and finds particular applicability in high frequency modulator tubes, for use with magnetrons for example. For this reason the invention will be described, by way of example only, as incorporated in a modulator tube. The invention resides in the novel construction of a magnetically focused electron gun including a new and improved magnet pole piece, and is especially concerned with the production of a strong, uniformly convergent magnetic field in the region of the cathode of the gun.

In an electron gun which uses a magnetic focusing field, a more compact unit can be obtained by embedding the electron gun within a cavity in a pole of the magnet which provides that magnetic field. In such a unit the magnetic field is made convergent in the region of the electron gun and tends to focus or converge the electrons into a dense stream or beam as they travel away from the cathode. This type of electron gun, known as a convergent beam gun, has some very special advantages. For example, it is highly desirable for producing high beam current densities since a large electron-emissive cathode area can be used to provide electrons for a relatively small cross section beam.

However, when an electron gun is used which has conventional wire wound grids interposed in the beam path adjacent the cathode, and when the magnetic field within the cavity is no stronger than that provided by prior art practice, serious problems of nonuniformity and low intensity of the beam are encountered. In the absence of a strong magnetic field in the cavity, the strong electric fields which always exist therebetween the grid wires focus the electrons of the beam into a series of very narrow parallel ribbons. Due to the resultant decreased size of the total actual beam cross section, the electron current which can flow may be reduced to as much as one tenth of the otherwise obtainable current. In Fig. 1, view *a* shows a perspective with cross section of a theoretically ideal beam of rectangular shape. View *b* shows a perspective with cross section of the same shape beam developed as a result of a weak magnetic field and strong electric fields between the grid wires. This is the type beam obtained by prior art practices. View *c* shows a perspective with cross section of the same shape beam obtained by use of the present invention. It will be noted that here the narrow parallel ribbons representing the partial cross sections of view *b* have been expanded to nearly fill the general outline of the overall cross section represented by view *a*. As a result the total current of the beam is correspondingly increased and a more uniform cross section provided.

Accordingly, one object of my invention is to obtain a convergent electron beam having the desired uniform composition and configuration of Fig. 1c.

To this end another object of my invention is to provide a convergent magnetic focusing field whose strength is relatively high within the cavity of a magnet pole piece.

These objects are accomplished in my invention by

making the magnet pole piece as a composite structure, with a body of low reluctance magnetic material and a capping plate of material of somewhat higher reluctance. A cavity having a constricting throat is formed through the higher reluctance plate into the low reluctance body. In the preferred embodiment the higher reluctance plate is made up of alternate laminations of magnetic and nonmagnetic material, with the laminations lying generally perpendicular to the beam axis. This results in a plate having a desired overall reluctance intermediate that of the magnetic and nonmagnetic materials.

The use of an intermediate reluctance plate on the face of the pole piece provides a relatively higher reluctance path to magnetic flux out of the front face than is obtained in a cavitated pole piece of all magnetic material. By so doing, flux spillage is enhanced from around the throat to within the cavity. After spilling into the cavity, the magnetic flux lines are bent and attracted to the opposite polarity pole a the far end of the tube. In this way a stronger convergent or funneling field is achieved within the cavity.

In the description of the present invention and in the accompanying claims the terms "magnetic," and "low reluctance" are used somewhat interchangeably and describe a similar property. Likewise, "nonmagnetic," and "high reluctance" are used interchangeably and describe a similar property. Each of the two pair of terms is used relative to the other to describe relative degrees of permeability. Within these terms of reference, soft iron might comprise a magnetic material and copper a nonmagnetic material.

In the remaining drawings:

Fig. 2 illustrates a simplified modualtor tube incorporating my invention.

Figs. 3 and 4 show a front elevation and longitudinal section view, respectively, of a pole piece as incorporated in the tube of Fig. 1. It is one preferred because of its simplicity for rectangular beam applications.

Figs. 5 through 10 show three other representative forms of cavitied magnet pole pieces which may embody my invention.

Figs. 11*a* and 11*b* illustrate by contrast, respectively, the shapes and relative strengths of the magnetic fields formed by a prior art pole piece and by the pole piece of my invention.

Referring to Fig. 2, the tube **1** includes a vacuum tight envelope **2** containing at one end thereof an electron gun assembly **4** for producing an electron beam **6**, at the other end an electron collector **8**, and intermediate the gun and collector an electrode system. The latter may be of any conventional form, for example with parallel electrodes **12** and **14**. Also included within the envelope **2** are two magnet pole pieces **16** and **18** for the purpose of providing the requisite magnetic focusing field. These may be either permanent magnets themselves or magnetically permeable pieces having associated therewith either an external permanent magnet or a solenoid which produces a magnetic field.

The entire electron gun assembly **4** is housed within the pole piece **16**, and comprises a unitary electron cage assembly which may include either conventional wire grids or conventional apertured disk electrodes. For example, the electron gun shown has a cathode **20**, a heater (not shown), a wire control grid **22**, a wire screen grid **24**, and an electron reflector **26**. The novel pole piece **16**, which is the subject of my invention, may be supported in any conventional manner.

Referring to Figs. 3 and 4, the pole piece **16** is cubical in general external shape. However, it should be understood that for successful practice of my invention it is not necessary that the overall outside shape be of any particular configuration. The pole piece **16** consists of

two main parts, a body member 28 of magnetic (low reluctance) material having a recess or channel 30 in one side thereof, and an intermediate reluctance slotted capping plate 42—44 in flush abutment with the channeled side of the body member 28. The capping plate is made up of alternate laminations of magnetic material 32 and nonmagnetic material 34. The magnetic material of both the body 28 and the plate 42—44 may be soft iron while the nonmagnetic material may be copper. A cavity 36 is provided in the composite pole piece 16 which opens from the channel 30 through the external face of the laminated plate. The cavity 36 is in the form of a dovetail-like channel and provides opposed tapered walls 38 and 40 on the plate 42—44 to assist in shaping the magnetic field. Such a pole piece may be fabricated from three parts; a horizontally, rectangularly channeled body member 28, and two laminated end plates 42 and 44 of trapezodial cross section. The shorter of the two parallel sides of each of the two laminated end plates is affixed in abutment with one of the faces of the channeled side of the body member such that a constricted entrance to the cavity is provided. An aperture 46 may be provided in the rear of the body member to enable lead wires to be brought into the electron gun elements. However, if the cavity is left with open sides then this aperture is not necessary since lead wires may be brought in from the open sides.

Figs. 5 and 6 show a front elevation and longitudinal section view, respectively, of a pole piece 47 identical to that of Figs. 3 and 4 with two exceptions: (1) the recess or channel 48 extends only across the central region of the pole piece thus providing a cavity 49 with side walls and (2) the intermediate reluctance capping plate 50 is fabricated from a solid homogeneous piece of a material such as an alloy possessing the characteristic of the desired intermediate reluctance.

Figs. 7 and 8 show corresponding views of a pole piece 51 identical to that of Figs. 3 and 4 except that its overall outside shape is circularly cylindrical.

Figs. 9 and 10 illustrate corresponding views of a pole piece 52 having a circular throat opening 53 adapting it for use where a beam of circular cross-section is desired. Here the cavity 54 has the shape of a right circular cylinder beveled on one end. This results in a convergent magnetic field with 360° symmetry rather than the planar symmetry about a horizontal center line as in the pole pieces of Figs. 3 through 8. The pole piece 52 also illustrates two modifications which may be incorporated either singly or in combination in this or any other of the embodiments of my invention. Here, the intermediate reluctance laminated front region 55 is provided by slotting an otherwise unitary pole piece of magnetic material. As such, the slots 56 are composed of the medium surrounding the pole piece, for example, a vacuum, and serve as the nonmagnetic laminae. As a further modification the laminae are convergent forward toward the center rather than being perpendicular to the direction of beam flow.

Referring now to Fig. 11*a*, a cavitied pole piece 57 is shown which consists of all magnetic material constructed according to the prior art. Most of the flux lines 58 are conducted around the cathode 59 and out through the front face 61 with very few spilling out of the body of the pole piece and into the cavity 63. However, the fact that flux lines are mutually repulsive results in their tendency to spread out by pushing away from each other. This fact in itself will cause some few lines to traverse a path out the pole piece 57 and into the cavity 63.

In the pole piece 16 according to my invention, as shown in Fig. 11*b*, the addition of an intermediate reluctance capping plate 42—44 on one face of the low reluctance portion 28 of the pole piece causes the spillage into the cavity to be more pronounced, giving a strong convergent or funneling field within the pole piece. This result obtains from the fact that the flux has two alternative paths which it can follow: out of the front face 64, or into the cavity 36. The addition of the capping plate 42—44 causes an unbalance in the relative reluctances of these alternative paths. The flux will then redistribute itself, and some of the lines that otherwise would have followed the path out of the front face will be diverted along the alternative path into the cavity. This action may be likened to an electrical circuit in which the resistance in one of two parallel paths is increased—the analogous result being an increase of current in the other path. It should be here noted that in Figures 11*a* and 11*b* the lines of force representation are meant to illustrate only a qualitative comparison and not a quantitative one.

Experimental results show that whereas a field of approximately 100 gauss inside the cavity was obtainable with prior art pole pieces, it is possible to approximate a 1500 gauss field inside the cavity by using a pole piece according to my invention. Such an increased field strength within the cavity prevents the electron beam from being formed into the narrow parallel ribbons as described in Fig. 1*b*.

In accordance with my invention the capping plate may simply be constructed of a solid piece of intermediate reluctance material as shown in Figs. 5 and 6. However, I have found that a laminated construction of alternate magnetic and nonmagnetic laminae offers some special advantages. In a laminated construction it is possible to conveniently obtain a desired predetermined reluctance of the capping plate by preselecting the relative thicknesses of the magnetic and nonmagnetic laminae. Moreover, if the laminations are oriented transverse or generally perpendicular to the direction of flux flow, the capping plate exhibits a higher reluctance in the direction out through the front face of the pole piece than it does in the general direction toward the cavity. As may well be appreciated from the foregoing explanation in reference to Figs. 11*a* and 11*b*, such a differential reluctance characteristic will act to enhance spillage.

I claim:

1. A magnet pole piece comprising a body member of low reluctance magnetic material and a plate of intermediate reluctance overlaid on one face of said body member, said pole piece having a cavity therein opening through said plate, said cavity having wall portions defined by said plate which are convergent toward the outer face of said plate to form a constricting throat in the region of said outer face.

2. A magnet pole piece for producing a convergent magnetic field comprising a body member of magnetic material having a recess therein and a laminated plate of alternate magnetic and nonmagnetic laminae having a tapered apetrure therethrough, said plate having its side of larger aperture in flush abutment with the recessed face of said body member, said aperture being substantially axially aligned with the opening of said recess and substantially identical in shape to the cross section of the beam to be produced, whereby the aperture of said laminated plate combines with the recess of said body member to form a throated cavity adapted to house an electron gun.

3. A beam tube including a magnet pole piece comprising a body member consisting of a block of low reluctance magnetic material having a cavity recess in one face thereof and a plate of intermediate reluctance with a rectangular aperture therethrough having at least two of its opposite sides convergently tapered, said plate having its larger aperture opening side in flush abutment with said recessed face, the larger opening of said aperture being substantially the same size as said recess and axially aligned therewith, and an electron gun mounted in the cavity formed by said recess and aperture for projecting a convergent beam through said aperture.

4. The beam tube according to claim 3, wherein said

plate of intermeidate reluctance comprises alternate laminae of magnetic material and nonmagnetic material.

5. In a beam tube adpated to use a rectangular-shape electron beam, a magnet pole piece for providing a convergent magnetic field to shape said beam comprising a block of magnetic material and a laminated plate of alternate magnetic and nonmagnetic laminae affixed to a face of said block in flush abutment, said pole piece having a dovetail channel therein formed through said plate and into said block having a constricting throat of relatively higher reluctance than that of said block, said channel providing a cavity adapted to house an electron gun.

6. In a beam tube adapted to use a circular convergent electron beam, a magnet pole piece for producing a convergent magnetic field having 360° symmetry about the axis of the beam comprising a body member of magnetic material, a laminated plate of alternate magnetic and

nonmagnetic laminae overlaid on one face of said body member, said pole piece provided with a throated cavity opening through the surface of said laminated plate and adapted to house an electron gun, said cavity having the shape of a right circular cylinder beveled on one end.

7. A magnet pole piece comprising a first portion of low reluctance magnetic material and a second portion of somewhat higher effective reluctance next to said first portion, said pole piece having a cavity therein opening through said second portion and including wall portions defined by said second portion which are convergent outwardly to form a constricting throat for said cavity.

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