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MAGNETIC STRUCTURES FOR TRAVELING WAVE TUBES

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2 Sheets-Sheet 1

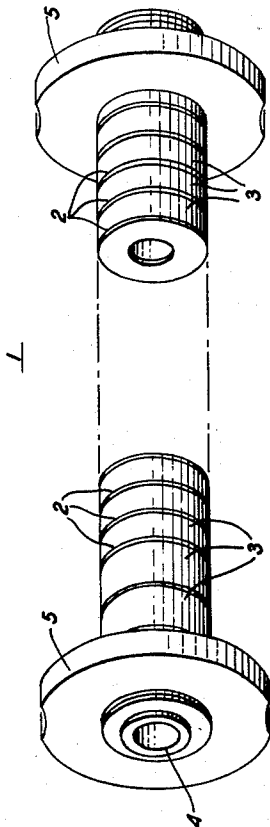


FIG. 1

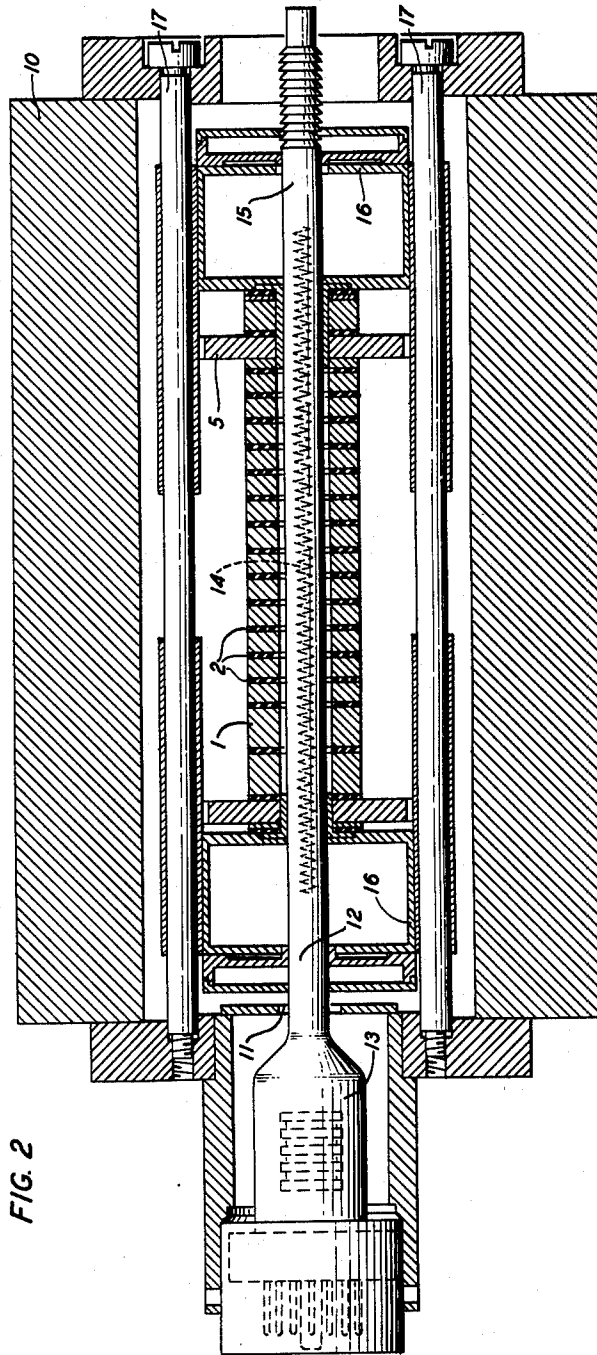


FIG. 2

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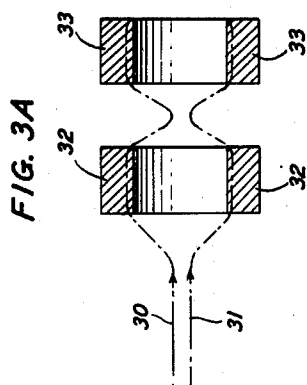
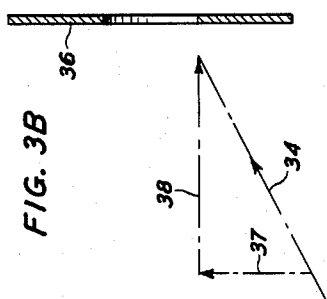
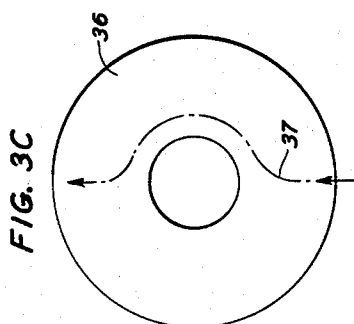


FIG. 4B

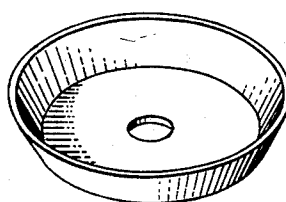
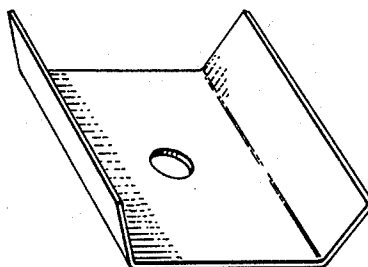


FIG. 4A



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MAGNETIC STRUCTURES FOR TRAVELING WAVE TUBES

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10 Claims. (Cl. 315—3.5)

This invention relates to traveling wave tubes and more particularly to such tubes wherein an electron beam is focused by a magnetic field along a relatively long path. This application is a continuation-in-part of application Serial No. 168,202, filed June 15, 1950.

In certain electron discharge devices, such as traveling wave tubes, an electron stream is projected into an interaction space generally defined by a helix, where it is made to interact with an electromagnetic wave traveling along the helix. Optimum operation is achieved when the electron stream is confined to a substantially cylindrical form having electrons at its radial extremities close to but not impinging the helix throughout the interaction space. It has been the practice to establish a longitudinal magnetic field along the path of electron flow to minimize transverse components of the electron stream caused chiefly by space charge effects and thus to confine the beam as desired.

A uniform longitudinal magnetic field of sufficient strength to offset the large space charge forces existing in an electron stream of high density over a relatively long electron path may be provided by a group of long parallel permanent magnets positioned about the interaction space as disclosed in the parent application, or by a single apertured permanent magnet as disclosed in M. S. Glass Patent 2,791,718, issued May 7, 1957, and in P. P. Cioffi Patent 2,871,395, issued January 27, 1959. One difficulty encountered in the use of such structures is that available permanent magnet materials are not sufficiently uniform in mechanical structure to provide entirely regular external fields. The resultant fields contain transverse components which may adversely affect the electron path through the interaction space.

It is an object of this invention to improve the magnetic focusing of electron streams in electron discharge devices such as traveling wave tubes.

More specifically it is an object of this invention to provide a magnetic field which will focus an electron stream over a relatively long path, confining the stream to a uniform shape within narrow limits.

Another object of this invention is to assure a precisely straight magnetic field by removing any transverse components present in the magnetic field.

Another object of the invention is to permit concentration of magnetic field at any position along the electron stream path.

In one specific embodiment of this invention four long permanent bar magnets may be used to provide the straight field for focusing the electron beam. Such magnets extend parallel to the axis of the traveling wave tube and are equally spaced around its periphery. In accordance with this invention a large number of transverse plates of a magnetic material are used to eliminate transverse irregularities in the magnetic field.

Specifically, in accordance with this invention, a series of spaced-apart apertured magnetic members are positioned about the interaction space in a traveling wave

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tube. The desired straight magnetic field is directed along the axis of the tube through the apertures in the magnetic members. The magnetic members are carefully aligned in parallel planes perpendicular to the field through the apertures so that transverse components of the field may be short-circuited.

The magnetic members are of high permeability material to provide a low reluctance path for such transverse field components, but are extremely thin so as not to exert an influence on the longitudinal field components. In this fashion the longitudinal field is not influenced by the magnetic members to divert its path and disrupt the strong straight field desired. However, the undesirable perpendicular component of transverse fields due primarily to imperfections in the field producing magnetic material, are removed from the interaction space by the magnetic members without disturbing the desired longitudinal components of such transverse fields.

By proper spacing and shaping of the thin magnetic discs, concentration of the longitudinal magnetic field in particular areas for optimum results with specific field producing magnet designs may be realized.

It is a feature of this invention that traveling wave tube apparatus comprise a plurality of spaced-apart high permeability magnetic members to shunt transverse components of a magnetic field passing through apertures in said members.

It is another feature of this invention that the magnetic members be made thin enough to affect only transverse components of the magnetic field.

It is a further feature of this invention that the magnetic members be positioned in parallel planes perpendicular to the longitudinal magnetic field.

It is a feature of one specific embodiment of this invention that the magnetic members be shaped at their extremities for increased field uniformity.

It is another feature of one specific embodiment of this invention that the spacing between magnetic members be varied to concentrate the field in desired locations.

A complete understanding of this invention and of the various features thereof may be gained from consideration of the following detailed description and the accompanying drawing in which:

Fig. 1 is a perspective view of a magnetic field straightener assembly utilized in one specific embodiment of this invention;

Fig. 2 is a side view in section of traveling wave tube apparatus utilized in one specific illustrative embodiment of this invention, employing the field straightener assembly of Fig. 1;

Fig. 3 demonstrates the effect of the field straightener assembly of Fig. 1 on the magnetic field; and

Fig. 4 shows two means for shaping the magnetic members in accordance with another specific embodiment of this invention.

Referring particularly to Fig. 1, the magnetic field straightener assembly shown generally as 1 comprises a series of thin discs 2 of high permeability material spaced apart by discs 3 of nonmagnetic material such as aluminum. The discs are apertured and mounted to permit alignment of the apertures, for example on a hollow mandrel 4, also of nonmagnetic material. Supports 5, adjacent the ends of the assembly, permit mounting of the assembly in the magnetic circuit of the traveling wave tube and adjustment relative to the axis of the assembly to assure precise perpendicular relationship between the parallel planes formed by the magnetic discs 2 and the magnetic field through the apertures.

The mounting is illustrated more clearly in Fig. 2 wherein a permanent magnet assembly 10 has a central aperture 11 along the axis of symmetry therethrough. The

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magnet assembly 10 forms a strong straight magnetic field along the axis of symmetry suitable for focusing an electron stream and may comprise four long permanent magnet bars. Other types of magnet structures known in the art such as disclosed in the priorly cited Glass and Cioffi patents, are suitable for this purpose, the instant magnet assembly 10 merely serving as an illustration of the proper environment for this invention. The traveling wave tube 12, which also may be of any type known in the art, is inserted into the aperture 11 between magnetic members 10 and extended through the field straightener assembly 1. The traveling wave tube essentially comprises an electron gun assembly 13 a helix transmission circuit 14 and an electron collector assembly 15. Wave guide input and output coupling means 16 are shown. The rods 17, seated in supports 5, assist in positioning of the field straightener assembly 1 so as to assure that the planes including the discs 2 are precisely perpendicular to the longitudinal magnetic lines of force extending along the helix portion of the tube 12 through the field straightener assembly 1.

The basic requirement of straight field focusing in contradistinction to periodic focusing as known in the art, is the provision of a strong straight magnetic field over a relatively long air space constituting the interaction space of a traveling wave tube. Careful design of the field-producing magnet permits provision of a substantially straight field. Nevertheless, imperfections of microscopic proportion in the magnetic material may create transverse fields which disrupt the desired operation. The magnetic discs 2 serve to attract and short-circuit the undesirable perpendicular components of these transverse fields. They are made extremely thin to assure that only the perpendicular field components are attracted by the low reluctance path they provide, while leaving the desirable longitudinal components of the transverse fields undisturbed.

The principle involved is illustrated in Fig. 3. It is known that provision of annular rings of magnetic material close to the path of the desired magnetic field results in field deviations as shown in Fig. 3a. The magnetic lines of force seek the path of least reluctance, and high permeability elements 32 and 33 provide a more attractive path than the air space therebetween. Thus longitudinal lines of force 30 and 31, which would otherwise maintain a straight path, are deviated substantially in the manner shown, thereby considerably weakening the field in the region between the magnets. This arrangement may be employed in various tube applications to obtain a periodically varied concentration of field along the electron beam path. It is apparent that the straight field along the interaction space, as desired in the instant application, is not achieved and the use of such rings merely accentuates field distortion.

In accordance with this invention, in order to assure an undisturbed longitudinal field and to remove elements of fields directed otherwise than in the precise desired direction, extremely thin discs of magnetic material closely spaced in parallel planes perpendicular to the desired magnetic field and apertured to receive the desired field, are utilized.

Transverse or stray fields comprising lines of force, such as 34 shown in exaggerated form for illustration in Fig. 3b, may exist in an otherwise straight field directed toward the apertures of thin magnetic discs such as 36. The transverse field line comprises components 37 and 38 perpendicular and parallel respectively to the direction of desired field. The magnetic discs such as 36, due to their extreme thinness, do not afford a path sufficiently lower in reluctance than the air space in the apertures to cause longitudinal magnetic lines of force through the apertures to deviate from their straight paths so as to pass therethrough. Thus the horizontal component 38 of line of force 34 will behave as though the magnetic discs were not present. The perpendicular component 37, however, is attracted by the high permeability discs 36 which afford

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a low reluctance path in its plane. The path of the perpendicular component 37 is substantially as shown in Fig. 3c; i.e., completely bypassing the aperture area and preventing its exercising any influence therein. Thus, in effect, the perpendicular components are short-circuited, and their harmful effect on the straight magnetic field is removed. The result is selective attraction of undesirable field components rather than substantially complete attraction of the field as achieved by the annular rings in Fig. 3a.

Magnetic disc configurations such as shown in Fig. 4a and Fig. 4b may be employed in specific applications of the field straightener assembly. The bent or cupped extremities of the discs serve to shunt portions of the longitudinal field, and the shunting effect may be varied by spacing the discs closer together adjacent the ends of the field producing magnet structure than adjacent the central portion thereof. This method shunting has the unique property that, while decreasing the field near the ends of the structure, it increases the field in the central portion. The property of eliminating undesirable transverse field components is retained and implemented primarily by the flat, inner portions of the discs perpendicular to the desired longitudinal field.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In an electron discharge device, means for producing a magnetic field along a longitudinal path, means for directing an electron stream along said path in said field, and a plurality of magnetic members aligned along said path with the largest dimension in planes perpendicular to said magnetic field along said path and positioned closer to said path than said magnetic field producing means so as to attract only transverse components of said field in said path, successive ones of said magnetic members being spaced-apart by an amount greater than the dimension of each of said members along said path.

2. Traveling wave tube apparatus comprising an elongated helical conductor, means for projecting a stream of electrons lengthwise of and in coupled relationship to said conductor, means for applying a longitudinal magnetic field along said conductor to focus said electron stream, and a plurality of coaxially aligned plates of high permeability apertured to receive said helical conductor and arranged in parallel planes transverse to the direction of said magnetic field along said conductor, successive ones of said plates being spaced-apart by an amount greater than the dimension of said plates transverse to said planes, the dimensions of said plates in said planes being greater than the dimension of said plates transverse to said planes.

3. Electron beam focusing apparatus comprising means for applying a longitudinal magnetic field along the electron beam path and a plurality of spaced-apart magnetic members apertured to receive the electron beam and aligned substantially in parallel planes transverse to said magnetic field along the electron beam path, and between said path and said magnetic field applying means, the dimension of said members in the direction of said field being less than both the spacing between adjacent of said members and the dimensions of said members in said parallel planes transverse to said magnetic field along the electron beam path so as to provide a short circuit path for transverse components of said magnetic field through said apertures.

4. Electron beam focusing apparatus in accordance with claim 3 wherein said magnetic members are annular plates of high permeability material.

5. Electron beam focusing apparatus in accordance with claim 4 wherein said magnetic members comprise

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a flat central portion and end portions angularly displaced from the plane of said central portion.

6. Electron beam focusing apparatus in accordance with claim 4 wherein each of said magnetic members is bent in the peripheral region substantially to a frusto-conical contour.

7. Electron beam focusing apparatus in accordance with claim 4 and further comprising low permeability solid members interjacent said high permeability magnetic members.

8. Electron discharge device apparatus comprising means for forming a magnetic field, means for projecting a stream of electrons through said magnetic field and a plurality of apertured spaced-apart discs of magnetic material aligned substantially in parallel planes surrounding said magnetic field and said electron stream, said discs being extremely thin so as not to attract components of said magnetic field directed perpendicular to said parallel planes.

9. Traveling wave tube apparatus comprising a plurality of apertured magnetic members and an elongated helical conductor extending in the apertures of said magnetic members, means for projecting a stream of electrons lengthwise of and in coupled relationship to said conductor, and permanent magnet means applying a longitudinal magnetic field along said conductor to focus said electron stream, said magnetic members being suspended between said permanent magnet means and said conductor in spaced-apart relation substantially in parallel planes mutually perpendicular to said magnetic field through said apertures and proportioned such that the amount of magnetic material in said members adjacent

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the apertures is sufficient to cause deviation only of components of said field which are initially directed other than perpendicular to said parallel planes, at least one of said plurality of magnetic members comprising extreme portions angularly displaced from the plane of the balance of said one member.

10. A traveling wave tube comprising means defining an interaction circuit, means for projecting a stream of electrons along said interaction circuit, magnetic means for providing a straight magnetic field for focusing said electron stream in said interaction circuit, and means for removing transverse components of said magnetic field adjacent said interaction circuit, said last-mentioned means comprising a plurality of thin magnetic plates of high permeability positioned in said magnetic field along said interaction circuit and perpendicular to the direction of said straight magnetic focusing field, successive ones of said plates being spaced-apart by an amount greater than the thickness of said plates.

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