March 31, 1964 E. C. DENCH 3,127,538

PACKAGED TRAVELING WAVE ELECTRON DISCHARGE DEVICE HAVING MAGNETIC DIRECTING MEANS

Filed Nov. 30, 1953 4 Sheets-Sheet 1

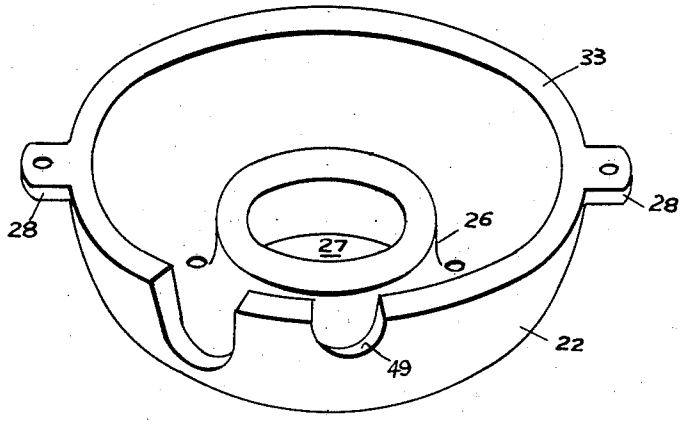


FIG. 1

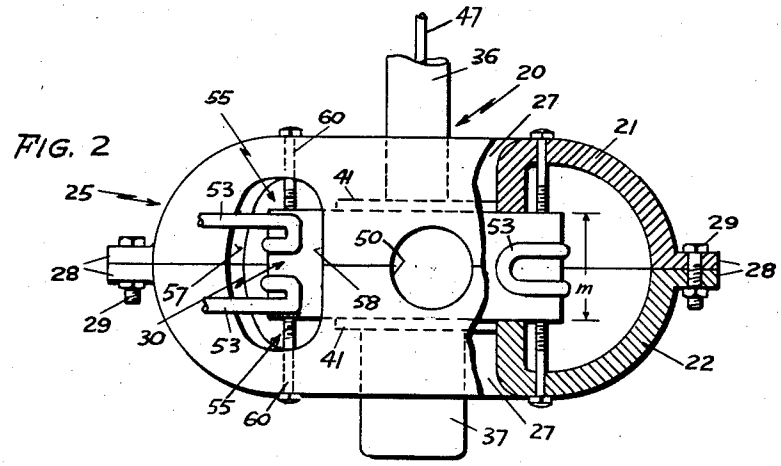


FIG. 2

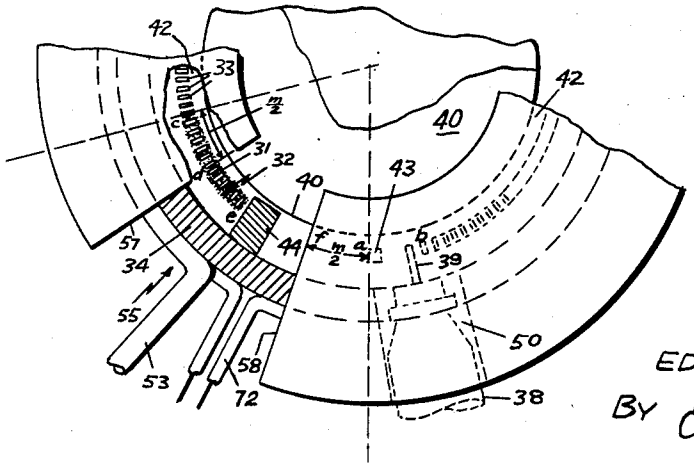


FIG. 3

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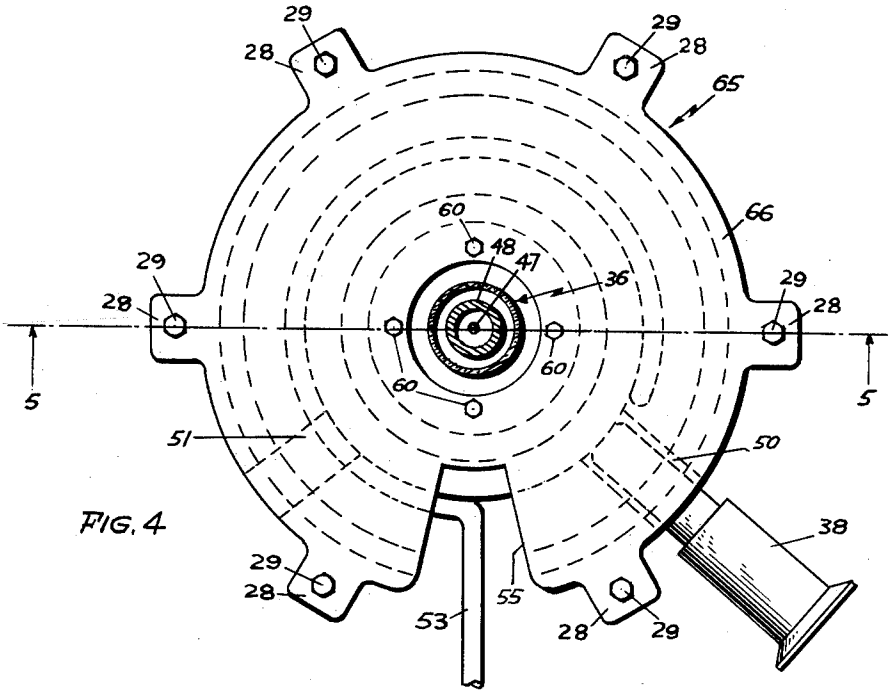


FIG. 4

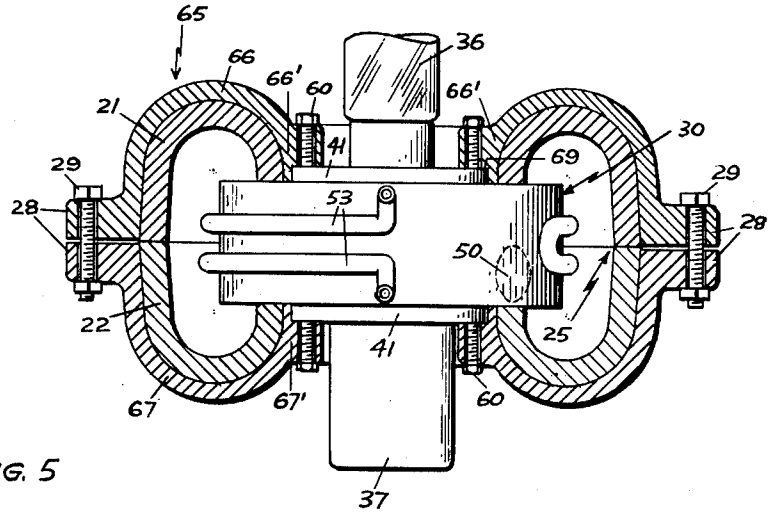


FIG. 5

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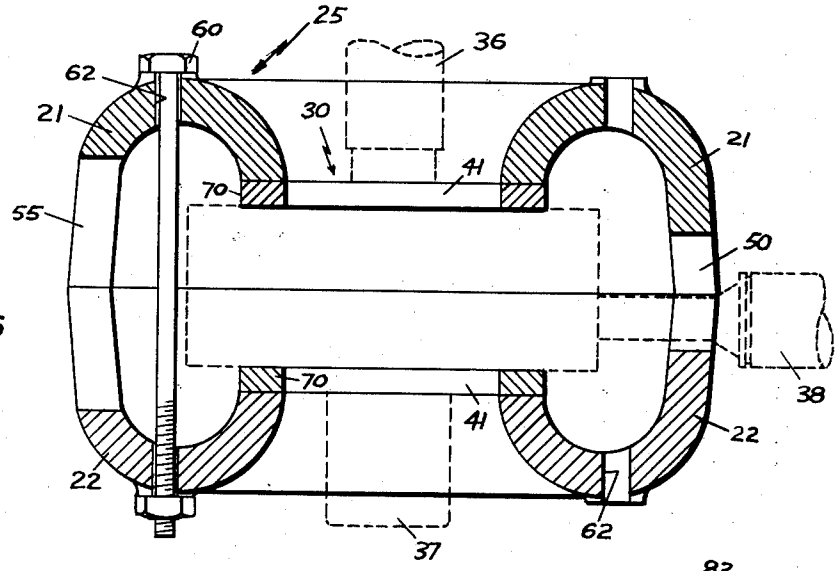


FIG. 6

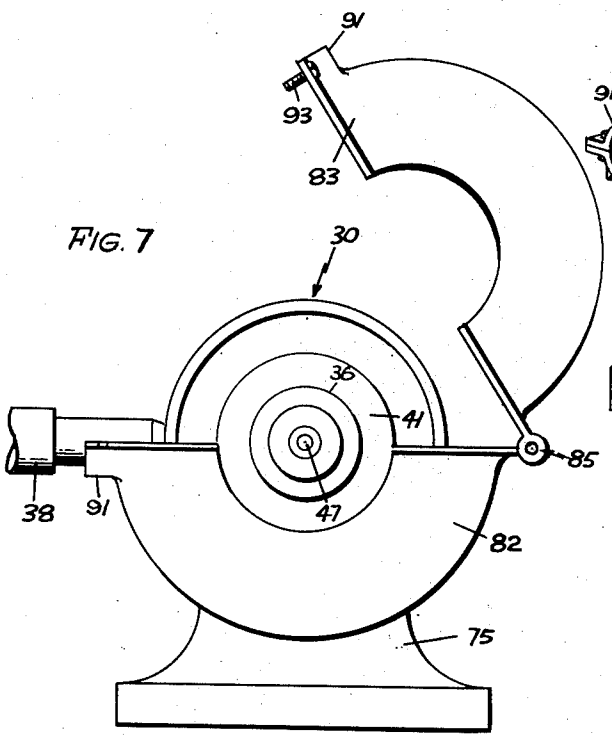


FIG. 7

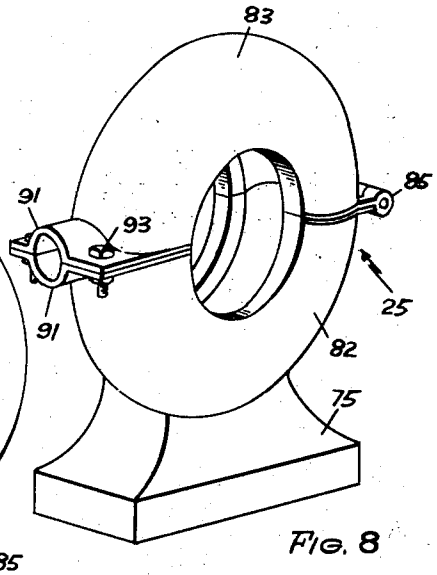


FIG. 8

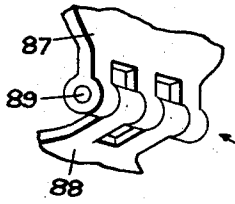


FIG. 9

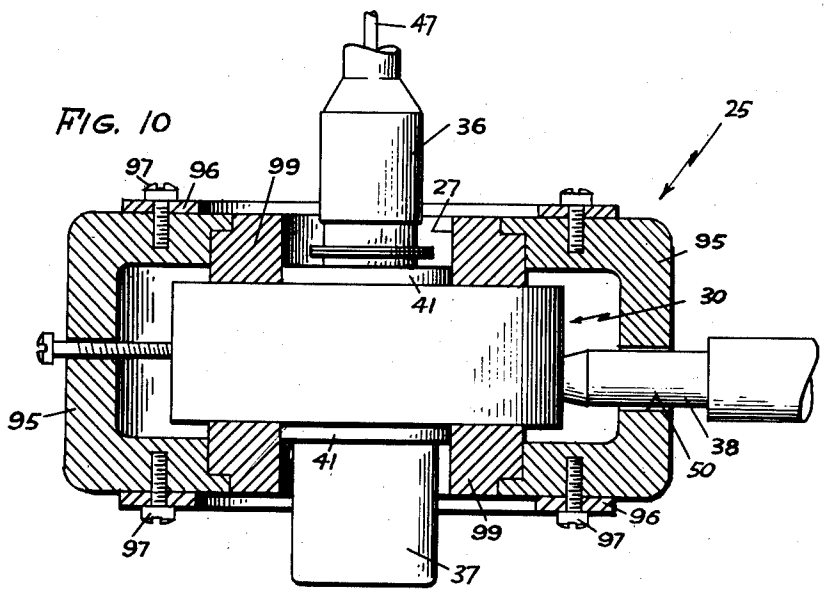
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FIG. 10



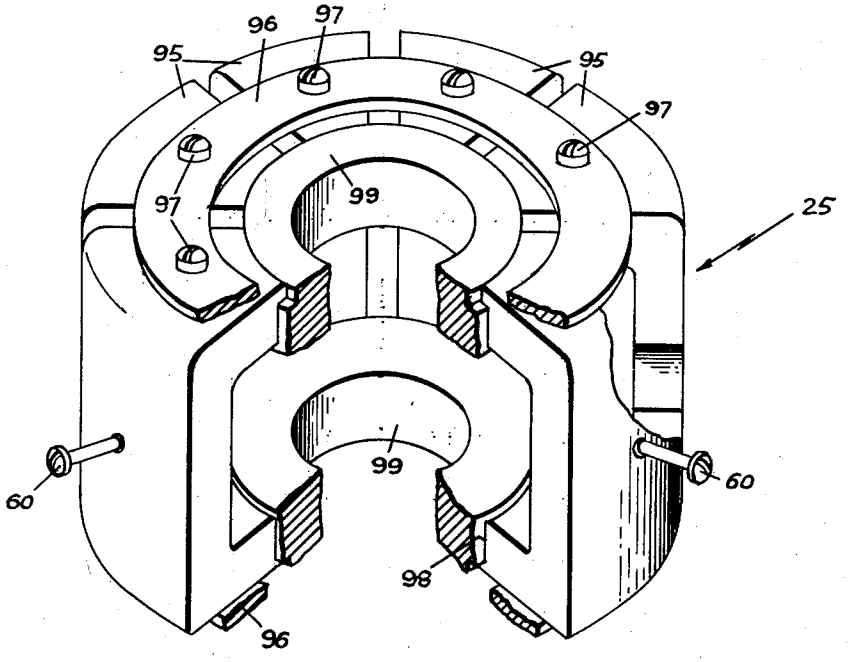


FIG. 11

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3,127,538

PACKAGED TRAVELING WAVE ELECTRON DISCHARGE DEVICE HAVING MAGNETIC DIRECTING MEANS

Edward C. Dench, Needham, Mass., assignor to Raytheon Company, a corporation of Delaware

Filed Nov. 30, 1953, Ser. No. 394,965
12 Claims. (Cl. 315—39)

This invention relates to a packaged electron discharge device of the traveling wave type in which the transverse magnetic field producing means forms an integral part of the device and further relates to a packaged magnet assembly used with said packaged device.

Electron discharge devices utilizing the interchange of energy between a periodically loaded non-reentrant anode delay structure, which may have an electrically attentuating region at one end, and an electron beam moving through mutually perpendicular electric and magnetic fields adjacent said structure are well known in the art. One example of such a device is shown and described in Patent No. 3,027,483, issued March 27, 1962 to Edward C. Dench.

Cylindrical traveling wave tubes are characterized generally by a narrow annular interaction space of relatively large radius, as compared with tubes of the magnetron type which have a relatively small interaction space which is more or less cylindrical. The magnets generally used in cylindrical traveling wave tubes have been either electromagnets or single C-shaped magnets whose pole pieces are adjacent the interaction space. Such magnets are characterized by considerable flux leakage and, consequently, the weight requirement for the given application is comparatively large. Furthermore, although C-magnets with cylindrical pole pieces are satisfactory in tubes of the magnetron type whose interaction space is more or less cylindrical and of relatively small area, such magnets are somewhat inefficient for use in cylindrical traveling wave tubes having an interaction space of the type described. For high values of flux density, electromagnets become quite bulky and require a constant current power supply if the magnetic field is to remain constant.

An object of this invention is to provide means for packaging an electron discharge device of the traveling wave type which includes a magnet as part of the device having narrow annular pole pieces of relatively large radius and which is characterized by light weight and a relatively low amount of leakage flux. This may be accomplished by means of a toroidal or quasi-toroidal magnet assembly surrounding the tube and having annular pole pieces which are substantially coextensive with and adjacent to the annular interaction space.

In one embodiment of the invention the magnet assembly is cast in two parts each having an apertured annular reentrant pole piece. The two parts are positioned about the tube and fastened together and the assembly magnetized by a gaussing coil. The tube is fixedly supported within this magnet assembly by appropriate means, such as bolts extending through the magnet assembly and tapped into the tube envelope.

This embodiment may be modified by casting the magnet inside a paramagnetic housing such as aluminum which provides protection for the magnet against external degaussing forces.

Alternately, the magnet may be made in two parts which are hinged together and fastened opposite the ends. With this arrangement the tube may be readily removed or changed by releasing the fastening means opposite said hinge, opening the magnet assembly and lifting out the tube.

A further modification of the invention involves an

assembly of a number of wedge-shaped C-magnets arranged in circular fashion each with their opposite ends in juxtaposition with two spaced magnetic rings serving as pole pieces. The various magnets are mechanically connected to form a unit surrounding the tube.

In all of these embodiments the magnet assembly may contain an inlet or access aperture through which a magnetizing coil may be inserted for magnetizing purposes. This aperture may also be used to accommodate a portion of a fluid cooling system in the event that the tube is to be fluid cooled. In locating this inlet aperture in applications involving a traveling wave oscillator, one boundary thereof is positioned substantially half the distance between pole pieces from the start of the attenuating region adjacent one end of the periodic anode structure, while the other boundary of said aperture is located substantially one-half gap length from the cathode adjacent the other end of said periodic structure.

It has been established that the magnetic field in the region adjacent a discontinuity in a pair of substantially parallel members spaced a distance m is not uniform. This field deviates from the normal uniform field by approximately one percent at a distance $m/2$ from said discontinuity. For practical purposes, deviations of one percent or less are considered tolerable. By locating the boundaries of the inlet aperture in the manner above described, therefore, the magnetic field adjacent the effective interaction space of the tube may be maintained uniform within plus or minus one percent.

Other and further objects of this invention will be apparent as the description thereof progresses, reference being had to the accompanying drawings wherein:

FIG. 1 is an isometric view of one of the halves of a toroidal magnet assembly used in a packaged traveling wave tube;

FIG. 2 is a view, partly in section, of a first embodiment of a packaged traveling wave tube showing the tube mounted within the magnet assembly formed by a pair of halves such as shown in FIG. 1;

FIG. 3 is a view showing the relative location of an inlet or access aperture in the toroidal magnet assembly with respect to certain portions of the tube structure;

FIG. 4 is a plan view of a modification of the packaged tube of FIG. 2 having a protective cover for the magnet, and further illustrating the relation between the tube and the cooling means;

FIG. 5 is a central cross-sectional view taken along line 5—5 of the packaged tube of FIG. 4, with the tube and cooling means shown in elevation;

FIG. 6 is a central cross-sectional view of a packaged traveling wave tube differing from that of FIG. 2 in the manner of assembling the halves of the toroidal magnet assembly;

FIGS. 7 and 8 are views showing a second embodiment of a packaged traveling wave tube having a hinged toroidal magnet assembly;

FIG. 9 is a detailed view showing the hinge portion of the magnet assembly of FIGS. 7 and 8;

FIG. 10 is a central cross-sectional view of a third embodiment of the invention having a magnet assembly comprising a plurality of circularly arranged magnets with the tube shown in elevation; and

FIG. 11 is an isometric view of the magnet assembly used with the packaged tube of FIG. 10.

Referring to FIGS. 1 to 3, a first embodiment of a packaged cylindrical traveling wave tube **20** comprises a pair of identical semi-toroidal shells **21** and **22** of ferromagnetic material, such as alnico, having a reentrant portion **26** bounding a centrally located aperture **27**. Each shell is provided with apertured lugs **28** for admitting fastening means such as bolts **29** for connecting

the two halves together, thereby forming an enclosed toroidal magnet assembly **25**. The surfaces **33** of the shells which are in contact with their opposite counterpart should be machined flat to prevent leakage of flux at this point and to aid in achieving good contact. Material may, if desired, be added to the magnet in the region adjacent this portion in order to insure positive contact between the halves of the magnet assembly.

Traveling wave tube **30**, which may be of the type shown and described in the aforesaid patent, comprises essentially an evacuated envelope containing a cylindrical non-reentrant periodic anode delay structure **32**, as shown in FIG. 3, which may include a plurality of interdigital fingers **33** extending from a circumferential back wall **34** forming a part of the evacuated envelope of the traveling wave tube. When operation as an oscillator is desired, a region of attenuation is provided at one end of the tube. As shown in FIG. 3, this takes the form of a coating **31** of an attenuating material such as iron applied as by electroplating to the fingers **33** near one end of the periodic delay line **32**. Other methods of introducing attenuation may, of course, be used. The envelope may also include a pair of circular cover plates brazed or otherwise securely attached to said back wall and described in detail in the aforesaid copending application. The details of construction of the tube envelope are clearly set forth in the aforesaid patent. One of these cover plates is apertured to receive a lead-in assembly **36** which contains the electrical connections to the various electrodes. This lead-in assembly, which includes a cathode lead **47**, is mechanically connected by a tubular supporting sleeve **48**, shown in FIG. 4, to a sole electrode **40** which is a cylindrical block of material coaxially arranged with respect to the anode structure and maintained at a negative potential with respect thereto. The details of the lead-in assembly, including the supporting sleeve and cathode lead, are shown in the aforesaid patent. Sole **40** is spaced from the periodic anode structure **32** by an annular interaction space **42** in which an electron beam from a cathode **43** is directed. An electric field is produced between the anode and cathode in the usual manner. The traveling wave tube further includes an exhaust tubulature **37** which is used in evacuating the tube. An output coupling means **38** is provided for extracting energy from one end of said periodic anode structure and includes an inner conductor **39** connected to an end finger thereof, as clearly shown in FIG. 3.

By subjecting the electrons emited from cathode **43** to the action of both the electric field and to a magnetic field transverse to said electric field, and produced in a manner to be described subsequently, the electron beam may be made to follow a substantially arcuate path around the interaction space. To prevent the electron beam from traversing the interaction space more than once, a collector electrode **44** may be provided which extends from the anode back wall almost to the sole. This interaction space **42**, although of relatively large radius is quite narrow, that is, of the order of 2.5 millimeters.

Since the flux lines should be concentrated in the annular interaction space **42**, the pole pieces of the magnet assembly also should be annular. The magnet assembly **25** is magnetized by inserting a gaussing or magnetizing coil **72** inside the toroidal shell after the tube has been assembled therein and exciting said coil from the usual source of unidirectional current, not shown. These annular pole pices are formed by the opposing reentrant portions **26** of the magnet assembly. The reentrant portions extend inwardly so that the gap *m* formed between the faces thereof, after assembly, is substantially equal to the thickness of the traveling wave tube envelope. The faces of the reentrant portions or pole pieces **26** should be machined flat within .005 inch and parallel to the end plates of the tube envelope in order to insure proper mounting of the tube within the magnet assembly and to prevent leakage of flux at this point. The ends of the

traveling wave tube preferably include projecting bosses **41** whose diameter is substantially equal to that of apertures **27**, thereby permitting proper alignment of the tube within the toroidal magnetic shells.

Lead-in assembly **36** passes through the centrally located aperture **27** of one shell while the oppositely disposed exhaust tubulature **37** protrudes from a centrally located aperture **27** in the other shell of the magnet assembly. The output coupling means **38** of the traveling wave tube is brought out through an aperture **50** formed by two aligned semicircular slots **49** in the magnet shells. This aperture should conform as nearly as possible to the output coupling means in order to minimize leakage flux and to maintain a uniform field in the region of the cathode for effective beam control.

Spaced from the output pipe **38** is an enlarged inlet aperture or access opening **55** in magnet assembly **25** for inserting the aforementioned magnetizing coil **48** and fluid conduits **53** forming part of the traveling wave tube cooling system. The magnetizing coil **48** is inserted between the wall of the toroidal magnet assembly and the circumferential wall of the tube envelope, as shown in FIG. 3. The tube thus serves roughly as a coil form about which the magnetizing coil **48** may be wound. The magnetizing coil is, of course, removed once the magnetization of the magnet assembly has been accomplished.

The fluid cooling system includes conduits **53** which are inserted within inlet aperture **55** and preferably are wrapped about the outside of the tube envelope, as clearly shown in FIGS. 2 and 3. The fluid cooling system may, in some instances, be eliminated, particularly where low power tubes are involved. However, because of the substantial enclosure of the traveling wave tube by the magnet assembly, some sort of cooling system for removing heat form the packaged tube is usually essential. The axial length of the access opening **55** depends upon the space required for insertion of the magnetizing coil and cooling conduits. If magnet design requires, the entire sector may be left open.

As previously mentioned, the anode structure of the traveling wave tube may comprise a region of attenuation. The portion *bc* of the periodic structure (see FIG. 3) is the effective portion over which energy interchange between the electron beam and the periodic structure occurs. The region *ce* adjacent the other end of the periodic structure is a region of electrical attenuation. Furthermore, in the region *ab* it is important that the magnetic field be uniform in order that the beam may be properly directed into the interaction space. It is also essential for proper operation of the tube that the transverse magnetic field be uniform in the region *bc* of effective interaction. The magnetic field adjacent the inlet aperture **55** through which the cooling pipes and magnetizing coil are inserted is somewhat distorted. It has been found that the magnetic field is uniform within one percent at points which are removed from the edge of the inlet aperture **55** by at least one-half the gap *m* between pole pieces **50**. Since the magnetic field must be uniform, at least up to the end (point *c*) of the non-attenuated portion of the anode delay line, the lateral boundary **57** of aperture **55** must be a half-gap distance removed from point *c*, that is, the distance *cd* should be *m*/2. Likewise, the magnetic field must be uniform adjacent cathode **43** for reasons previously stated, so that boundary **58** of inlet aperture **55** must be at least one-half gap length from the edge of the cathode; that is, the distance *af* is made substantially *m*/2. In this way, the inlet or access aperture **55** is located in the region of the tube where the magnetic field need not be uniform.

The traveling wave tube may be prevented from rotation within the magnet assembly by means of set screws **60** extending through apertures in the magnet shells **21** and **22** and resting against the end plates of the tube envelope. Alternately, the screws may be tapped into the tube envelope.

In FIGS. 4 and 5, the magnet assembly 25 is covered with a cast paramagnetic toroidal sheath 65 such as aluminum divided into two portions 66 and 67 which conform to the corresponding magnet shells. This sheath protects the magnet assembly from degaussing caused by external blows, contact with magnetic objects, and the like. The two halves of the sheath have a plurality of apertured lugs 28 for receiving bolts 29 which hold together not only the two halves of the sheath but also the magnet shells enclosed thereby. The surface of the lugs may be flush to the magnet base or may be slightly under flush, as shown in FIG. 5, to compensate for irregularities in the assembly. The reentrant portions 66' and 67' of sheath 65 may contain steps or recesses 69 in which the projecting bosses 41 of the tube envelope may fit. This allows proper positioning of the tube within the magnet assembly. To prevent rotation of the tube within the magnet assembly and to positively mount the tube therein, the reentrant portions 66' and 67' are bored to receive screws 60 which may be threaded into the bosses 41 on the tube envelope. The lead-in assembly 36 and exhaust tubulature 37 protrude from apertures in the sheath and the magnet, in the manner previously described.

In order to make the two halves of the magnet assembly completely identical, an additional aperture 51 may be provided, as shown in FIG. 4, which is symmetrically located with respect to apertures 50. In most applications, however, aperture 51 may be dispensed with.

A modification of the packaged tube of FIGS. 4 and 5 is shown in FIG. 6 in which the magnet assembly 25, like that of FIGS. 1 to 3, is left uncovered. A soft iron ring 70 is positioned in contact with each end of the reentrant portions of the alnico magnet shells 21 and 22, as shown in FIG. 6. These rings provide a more uniformly concentrated flux in the annular magnet gap. In addition, the magnet halves are connected directly by means of elongated bolts 60 passing through aligned apertures 62 clear through the magnet assembly 25.

In FIGS. 7 to 9 a packaged tube is shown in which tube 30 is mounted with its axis horizontal and parallel to a mounting base 75. The toroidal magnet assembly consists of a fixed lower portion 82 which may be attached to base 75. The toroidal magnet assembly of FIGS. 7 to 9 may be clad with a protective casing, such as aluminum, in the manner shown in FIG. 5. If such a casing were used, the casing for the lower portion 82 and the base 75 could be an integral member. The upper portion 83 is movable about a hinge 85 shown in detail in FIG. 9. Each half of the magnet assembly has forked protuberances 87 and 88, respectively, through which a hinge pin 89 may be inserted. At the end of each portion of the magnet assembly opposite the hinge is a locking flange 91 having a central arcuate collar adapted to receive the circular output coupling means 38. Whether or not the output coupling means is circular the collar obviously will be made to conform thereto. The two portions of the magnet assembly are bolted together by means of bolts 93 passing through the flat portion of the flange on either side of the collar. The two halves of the magnet assembly may be fastened together by clamps or by screws threadedly inserted in an opening in flange 91.

This tube may be prevented by rotation by virtue of the close tolerance or frictional fit between the output coupling means and the collar by means of set screws, not shown, extending through holes in the magnet assembly, in the manner shown in FIGS. 1 and 2. A close tolerance between the output coupling means 38 and locking flange 91 is desirable in order to minimize flux leakage and to maintain a uniform magnetic field in the region of the output pipe 38 for effective beam control. Tube 30 may be securely mounted within the magnet assembly by means already set forth.

To remove the traveling wave tube 30 of FIGS. 7 to 9, it is necessary only to unfasten the flanged end of the magnet assembly, lift the upper portion 83 of the magnet assembly away from the lower portion about hinge 85, and lift out the tube.

In FIGS. 10 and 11, a further embodiment of the invention is shown in which the magnet assembly comprises a number of wedge-shaped C-magnets 95. The curved central portion of the C-magnets may be increased in thickness, if desired, in order to supply as much magnetomotive force as possible. These magnets are somewhat easier to fabricate and also more amenable to heat treatment than the toroidal magnets previously described. Magnets 95 are arranged in circular fashion so that the pole pieces 98 are in alignment, forming, in effect, a pair of spaced broken rings. The various magnets are assembled by means of a pair of mounting rings 96, each of which is fastened to the individual magnets at one end thereof by screws 97 preferably inserted in tapped holes in the magnet. The rings may also be fastened to the magnets by bolts passing through the magnet legs. The mounting rings may be made of any material having sufficient strength and rigidity, as for example, brass, aluminum or stainless steel.

In order to produce a uniform annularly disposed field perpendicular to the interaction space of the tube and coextensive therewith, the individual pole pieces of the C-magnets are positioned in engagement with continuous circular rings 99 which preferably make contact with the end walls of the tube envelope, as shown in FIG. 10. These rings 99 thus form annular pole pieces necessary for effective operation of traveling wave tubes. The circular rings 99 and the pole pieces of the C-magnets 85 may be notched, as shown in FIGS. 10 and 11, so that the rings may be prevented from lateral displacement, once assembled. With the arrangement shown, the circular rings need not be permanently attached to the C-magnets and the traveling wave tube may be replaced by merely removing one of the mounting rings 96. The tube may be centered within the magnet assembly 25 by means of bosses 41 which are slightly smaller than the inside diameter of the mounting rings 96. Rotation of the tube is prevented by means of set screw 60. The lead-in assembly 36 and exhaust tubulature 37 are brought out through annular pole pieces 99 and the output coupling means 38 is brought out through aperture 50 in one of the C-magnets or through an aperture formed by arcuate slots cut in adjacent C-magnets. An aperture, not shown, may also be provided through one or more of the C-magnets to allow for insertion of water cooling tubes, in the manner previously described.

In addition to providing an annular air gap, the circular rings 99 serve to eliminate the non-uniform field which would otherwise exist because of the gaps between adjacent magnets.

The magnets 95 of FIGS. 10 and 11, as well as the toroidal magnet assembly 25 of FIGS. 1 and 2, 6, and 7 to 9 may be protected from external degaussing effects such as blows from or contact with ferromagnetic objects, by means of insulating tape, plastic coating compound, or an aluminum jacket such as shown in FIGS. 4 and 5.

The assembly of FIGS. 10 and 11 may be hinged in the manner shown in FIGS. 7 to 9 so as to allow more readily access to the traveling wave tube.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A traveling wave tube comprising an evacuated envelope containing therein a periodic slow wave energy transmission structure for propagating electromagnetic wave energy along a predetermined path adjacent said structure, and said tube further including a lead-in assembly extending from said structure, a source of electrons, di-

rective means including means for producing a magnetic field transverse to said path for directing said electrons from said source adjacent said path in energy coupling relationship with said wave energy, said magnetic field producing means surrounding said tube envelope and including a centrally located aperture for receiving said lead-in assembly of said tube, said magnetic field producing means further including at least one reentrant annular portion mounted in substantial alignment with said path, and means for fixedly mounting said tube within said magnetic field producing means.

2. In combination, a traveling wave tube having an evacuated envelope containing therein a slow wave energy transmission structure for propagating electromagnetic wave energy along a predetermined path, an output coupling means coupled to said structure, said tube further including a portion extending from said structure, a source of electrons, and directive means including means for producing a magnetic field transverse to said path for directing said electrons from said source adjacent said path in energy coupling relationship with said wave energy, said magnetic field producing means substantially surrounding said tube envelope and including a centrally located aperture for receiving said portion of said tube, said magnetic field producing means further including a pair of inwardly projecting annular portions arranged coextensive with said path, and an access opening disposed substantially perpendicular to said centrally located aperture for receiving said output coupling means.

3. In combination, an electron discharge device having an evacuated envelope containing therein a substantially cylindrical slow wave energy transmission structure for propagating electromagnetic wave energy along a predetermined path, output coupling means coupled to said structure, a source of electrons, directive means including means for producing a magnetic field transverse to said path for directing said electrons from said source adjacent said path in energy coupling relationship with said wave energy, said tube further including a lead-in assembly disposed normal to said structure, a centrally disposed aperture in said magnetic field producing means for receiving said lead-in assembly, said magnetic field producing means substantially surrounding said tube envelope and including a pair of reentrant annular portions arranged adjacent to and coextensive with said path, said magnetic field producing means further including an access opening perpendicular to said centrally disposed aperture for receiving said output coupling means, and means for fixedly mounting said tube within said field producing means.

4. In combination, an electron discharge device including an evacuated envelope containing a periodic frequency responsive energy transmission structure of substantially cylindrical configuration having an attenuating region at one end thereof, a principal electrode coaxially arranged with respect to said transmission structure to form an interaction space therebetween, and a source of electrons positioned adjacent one end of said periodic structure, means including a magnet assembly for establishing a magnetic field transverse to said interaction space and capable of directing said electrons therethrough, fluid cooling means partially surrounding said evacuated envelope and mounted within said magnet assembly, said magnet assembly containing centrally located apertures closed by said envelope and having reentrant annular portions, said portions contacting said envelope and arranged coextensive with said interaction space, said magnet assembly combining with said electron discharge device to form a closed magnetic path, said magnet assembly containing an inlet aperture for receiving said fluid cooling means, said inlet aperture having boundaries displaced substantially one-half the distance between said pole pieces from said cathode and from one end of said attenuating region, respectively, and means for fixedly mounting said electron discharge device within said magnet assembly.

5. In combination, an electron discharge device including an evacuated envelope containing a periodic energy transmission structure of substantially cylindrical configuration having an attenuating region at one end thereof, a principal electrode coaxially arranged with respect to said transmission structure to form an interaction space therebetween, a source of electrons positioned adjacent one end of said periodic structure and output coupling means extending radially from said transmission structure; means including a magnet assembly for establishing a magnetic field transverse to said interaction space and capable of directing said electrons therethrough; fluid cooling means having a portion positioned within said magnet assembly and surrounding said envelope, said magnet assembly containing oppositely disposed centrally located apertures substantially closed by said electron discharge device, said magnet assembly including reentrant annular portions coextensive with said interaction space to form an air gap, an output aperture perpendicular to said centrally located apertures for receiving said output coupling means, and an inlet aperture spaced from said first aperture for permitting entrance of said fluid cooling means, said inlet aperture having boundaries displaced substantially one-half gap length from said electron source and from one end of said attenuating region, respectively, and means for fixedly mounting said electron discharge device within said magnet assembly.

6. In combination, an electron discharge device including a main body portion further including a periodic energy transmission structure of substantially cylindrical configuration having an attenuating region at one end thereof, a principal electrode coaxially arranged with respect to said transmission structure to form an interaction space therebetween, a source of electrons positioned adjacent one end of said periodic structure; means including a magnet assembly initially magnetized by a gaussing coil inserted therein for establishing a magnetic field transverse to said interaction space and capable of directing said electrons therethrough; said electron discharge device further including a first auxiliary portion including a lead-in assembly and exhaust tubulation disposed normal to said main body portion, a second auxiliary portion including output coupling means extending radially from said transmission structure; fluid cooling means surrounding said main body portion; said magnet assembly containing centrally located apertures for receiving said first auxiliary portion of said device, said magnet assembly including reentrant annular pole pieces coextensive with said interaction space to form an air gap, an output aperture perpendicular to said centrally located apertures for receiving said second auxiliary portion, and an inlet aperture spaced from said output aperture for receiving said gaussing coil and said fluid cooling means; said inlet aperture having boundaries displaced substantially one-half gap length from said electron source and from one end of said attenuating region, respectively; and means for fixedly mounting said electron discharge device within said magnet assembly.

7. In combination, a traveling wave tube including a periodic slow wave energy transmission structure for propagating electromagnetic wave energy and a principal electrode maintained negative with respect thereto, said periodic structure and said principal electrode being concentrically arranged and spaced from one another to form an annular interaction space, a source of electrons, directive means for directing said electrons from said source through said interaction space in energy coupling relationship with said wave energy, said tube further including auxiliary portions disposed normal to said periodic structure and principal electrode, said directive means further including means for producing a magnetic field transverse to said interaction space, said magnetic field producing means comprising a pair of substantially identical shells of magnetic material fastened together to form a toroidal

envelope surrounding said periodic structure and principal electrode, said shells having centrally located aligned apertures for receiving the auxiliary portions of said tube and further having cylindrical reentrant portions forming annular pole pieces adjacent to and coextensive with said interaction space, and means for fixedly mounting said tube within said toroidal envelope.

8. In combination, a traveling wave tube including a periodic slow wave energy transmission structure for propagating electromagnetic wave energy and having an attenuating region adjacent one end thereof and a principal electrode maintained negative with respect thereto, said structure and said principal electrode being concentrically arranged and spaced from one another to form an annular interaction space, a source of electrons, directive means for directing said electrons from said source through said interaction space in energy coupling relationship with said wave energy, said tube further including auxiliary portions disposed normal to said periodic structure and principal electrode, said directive means further including means for producing a magnetic field transverse to said interaction space, said magnetic field producing means comprising a pair of substantially identical shells of magnetic material fastened together to form a toroidal envelope surrounding said periodic structure and principal electrode, said shells having centrally located aligned apertures for receiving the auxiliary portions of said tube and further having cylindrical reentrant portions forming annular pole pieces adjacent to and coextensive with said interaction space, said field producing means containing an access opening having boundaries displaced substantially one half the distance between pole pieces from said electron source and from one end of said attenuating region, respectively, and means for fixedly mounting said tube within said toroidal envelope.

9. A traveling wave tube comprising an evacuated envelope containing a periodic energy transmission structure for propagating electromagnetic wave energy and a source of electrons, and directive means for directing said electrons from said source along an arcuate path in energy coupling relationship with said wave energy, said tube further including auxiliary portions disposed normal to said anode and principal electrode, said directive means further including means for producing a magnetic field transverse to said path, said magnetic field producing means comprising a pair of substantially identical shells of magnetic material, a pair of paramagnetic members positioned over a corresponding one of said shells, means including an integral part of said members for fastening said shells together to form a toroidal enclosure surrounding said evacuated envelope, said shells having cylindrical reentrant portions forming annular pole pieces adjacent to and coextensive with said electron path.

10. A traveling wave tube comprising an evacuated envelope containing a periodic energy transmission structure for propagating electromagnetic wave energy and a source of electrons positioned adjacent one end of said periodic structure, and directive means for directing said electrons from said source along an arcuate path in energy coupling relationship with said wave energy, output coupling means extending radially from said transmission structure, said directive means further including means for producing a magnetic field transverse to said path, and comprising a first stationary semi-toroidal shell of magnetic material forming an integral part of a base portion, a second semi-toroidal ferromagnetic shell movable with respect to said first shell, said shells each including means for receiving said output coupling means, said first and second shells combining to form a toroidal magnetic enclosure surrounding said tube, said shells each having a cylindrical reentrant portion forming spaced annular pole pieces, means for hingedly mounting said first and second shells about an axis parallel to the plane of said base portion, means for fastening said shells together in the vicinity of said output coupling means, and means for fixedly mounting said tube within said magnetic enclosure.

11. In combination, a traveling wave tube including a periodic non-reentrant energy transmission structure for propagating electromagnetic wave energy and having an attenuating region adjacent one end thereof, and a principal electrode spaced from said structure to form an annular interaction space therebetween, a source of electrons positioned adjacent one end of said periodic structure, directive means for directing said electrons from said source along an arcuate path through said interaction space in energy coupling relationship with said wave energy, output coupling means extending radially from said periodic structure, said tube further including auxiliary portions disposed normal to said and principal electrode, said directive means further including means for producing a magnetic field transverse to said interaction space and comprising a first stationary semi-toroidal shell of magnetic material forming an integral part of a base portion, a second semi-toroidal ferromagnetic shell movable with respect to said first shell, said shells each including means for receiving said output coupling means, said first and second shells combining to form a toroidal magnetic enclosure substantially surrounding said tube, said first and second shells containing centrally located aligned apertures for receiving said auxiliary portions of said tube, said shells further having a cylindrical reentrant portion bounding said apertures and forming spaced annular pole pieces, means for hingedly mounting said first and second shells about an axis parallel to the plane of said base portion, means for fastening said shells together in the vicinity of said output coupling means, fluid cooling means positioned within said envelope in thermal contact with said tube, said magnetic envelope containing an inlet aperture for permitting entrance of said fluid cooling means, said inlet aperture having boundaries displaced substantially one half the distance between pole pieces from said electron source and from one end of said attenuating region, respectively, and means for fixedly mounting said tube within said magnetic enclosure.

12. In combination, an electron discharge tube including an evacuated envelope containing therein a slow wave energy transmission structure of substantially cylindrical configuration, a principal electrode coaxially arranged with respect to said transmission structure to form an arcuate interaction space therebetween, a source of electrons spaced from said structure, and output means coupled to said transmission structure and extending radially therefrom, means for directing said electrons along said interaction space including a magnet assembly external of said tube envelope for establishing a magnetic field transverse to said interaction space, said magnet assembly including a pair of oppositely disposed annular pole pieces externally contacting said envelope and arranged adjacent to and coextensive with said interaction space, said magnet assembly and said electron discharge tube forming a closed magnetic path, an access opening disposed in said magnet assembly for receiving said output means, and means for fixedly mounting said electron discharge device within said magnet assembly.

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