BEAM TUBE AND MAGNETIC CIRCUIT THEREFOR

Filed Aug. 31, 1961 4 Sheets-Sheet 1

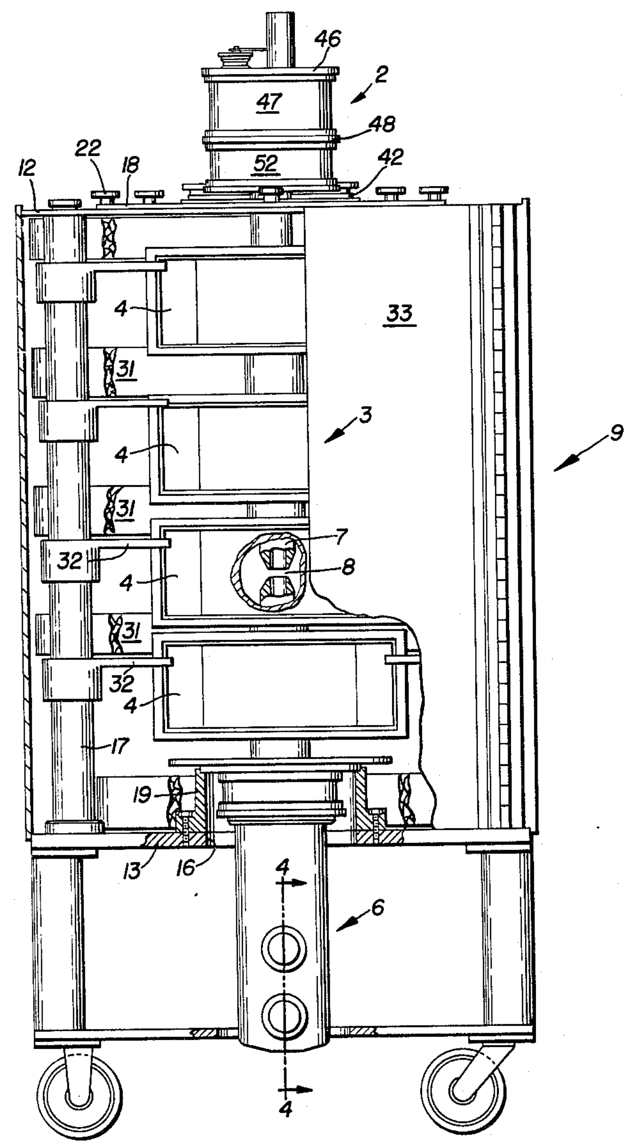

Fig. 1

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July 5, 1966 A. A. GOLDFINGER 3,259,790

BEAM TUBE AND MAGNETIC CIRCUIT THEREFOR

Filed Aug. 31, 1961 4 Sheets-Sheet 2

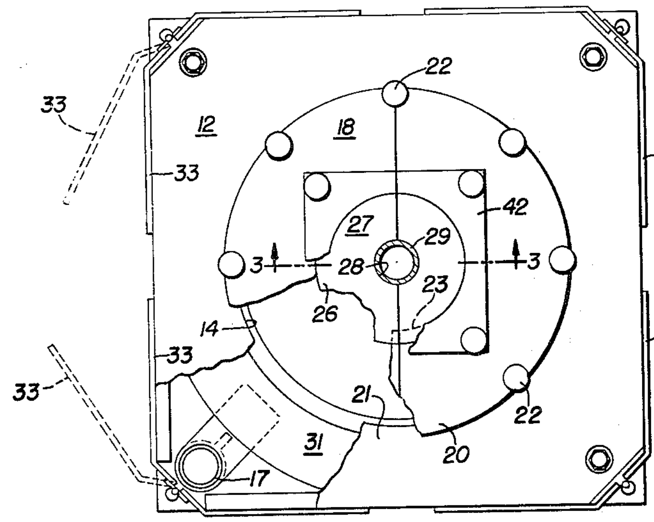

Fig. 2

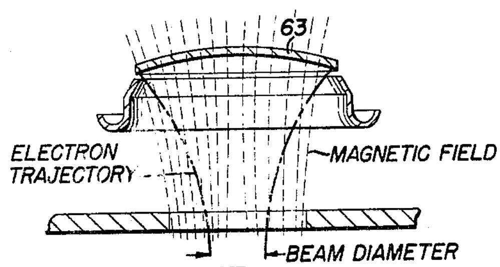

Fig. 5

PRIOR ART

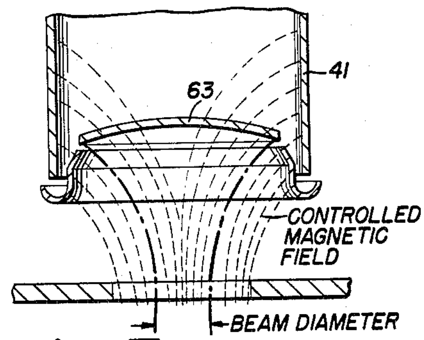

Fig. 6

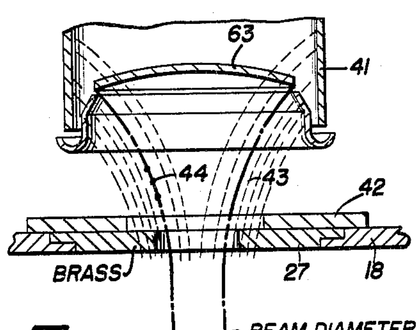

Fig. 7

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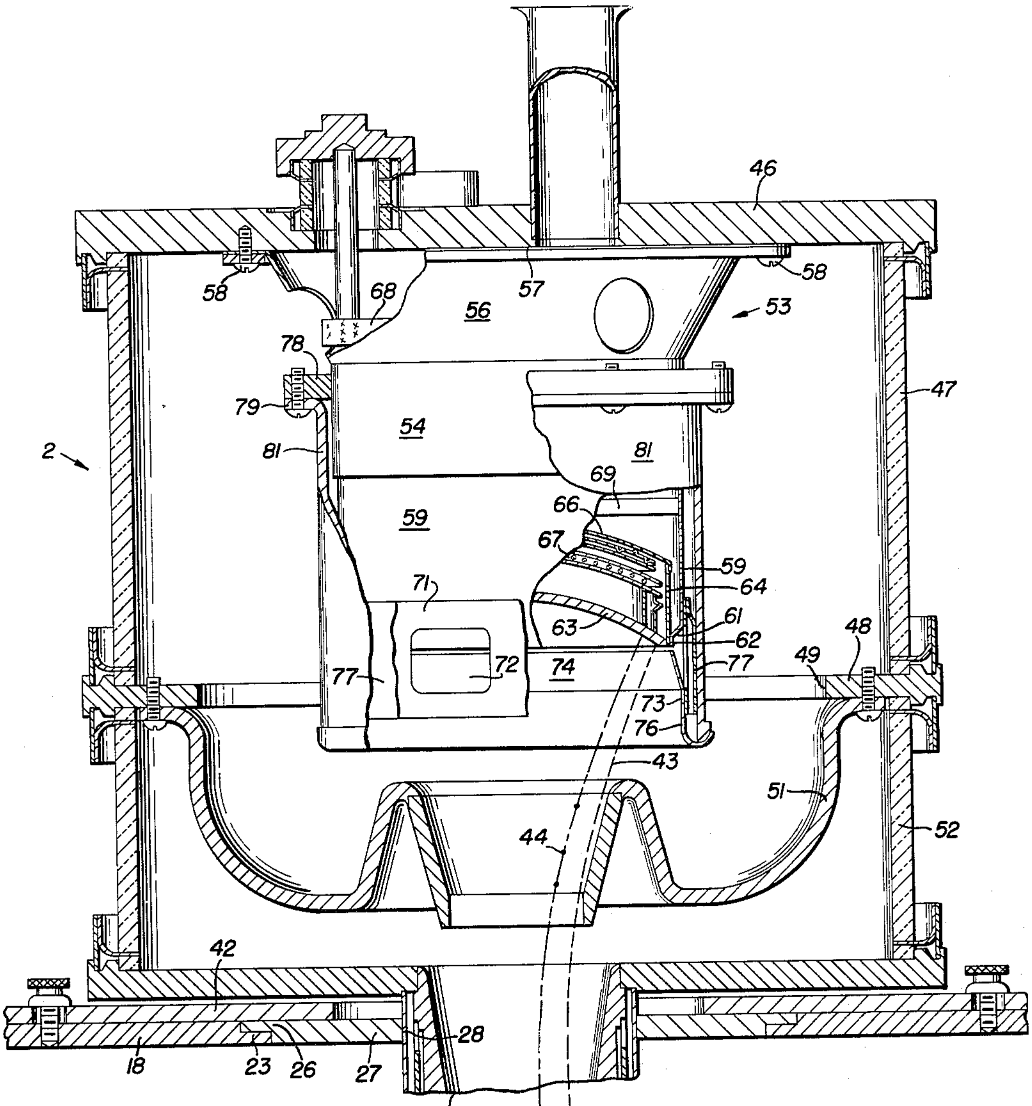

Fig. 3

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BEAM TUBE AND MAGNETIC CIRCUIT THEREFOR

Filed Aug. 31, 1961 4 Sheets-Sheet 4

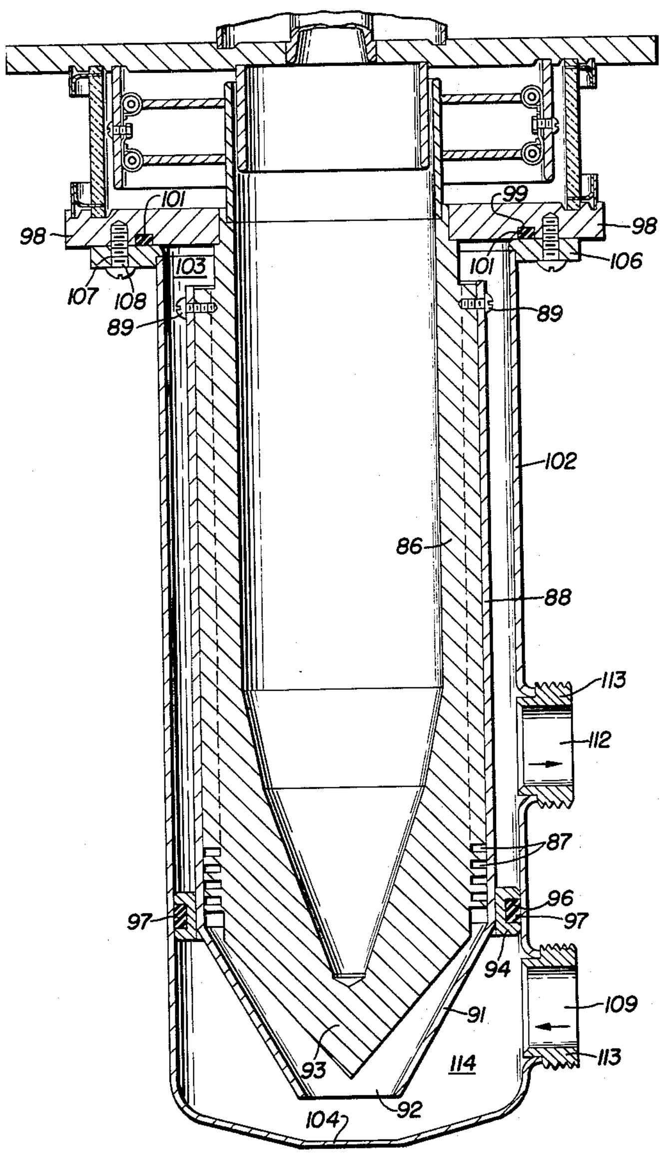

Fig. 4

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United States Patent Office

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BEAM TUBE AND MAGNETIC CIRCUIT THEREFOR

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Filed Aug. 31, 1961, Ser. No. 135,323
11 Claims. (Cl. 315—5)

This invention relates to beam tubes, and more particularly to the beam projecting and collecting portions thereof and to magnetic beam convergence and control systems therefor.

In beam tubes of all types, one of the basic requirements is that the electron beam that is generated be projected through the tube and related structure exactly on the axis of such structure. The reason for such a stringent requirement is that interception of the electrons of the beam by associated structure causes the structure to heat, giving rise to many other disadvantageous results. High power-high frequency beam tubes utilizing a narrow pencil-like electron beam of high perveance usually incorporate dish-shaped cathodes of relatively large area, and the convergence ratio is therefore quite high, in the order of 60 to 1. To effect such convergence of the electrons, beam forming electrodes of various configurations have been used. By controlling the configuration of the beam forming electrodes, and the electrostatic charge on selected ones thereof, electrostatic field lines of a particular pattern of distribution may be produced to control the electrostatic convergence of the electrons emitted from the cathode. In conventional beam tubes such as klystrons and traveling wave tubes, the cathode, focus electrode and accelerating anode cooperate to converge the beam in the proper ratio.

After the beam has been converged or compacted into a pencil-thin stream of electrons, the inherent space charge of the electrons in the beam tends to cause the beam to disperse and impinge on related structure. To minimize this dispersion of electrons in the beam, most conventional beam tubes utilize very strong magnetic fields which to some extent hold the electron beam captive, but which nevertheless permit some "scalloping" of the beam. Scalloping results from the tendency of the electrons to disperse due to a radial velocity component, thus tending to increase the beam diameter, and the tendency of the magnetic field to constrict the beam in opposition to the tendency of the electrons to disperse. These oppositely directed tendencies result in the beam having an undulating or scalloped configuration which is undesirable. Scalloping is aggravated when the beam is constricted too much for a given size drift tube. The constricting magnetic fields are usually generated by means of electromagnetic coils or permanent magnets interposed between appropriate pole pieces adjacent each end of the electron beam. Such pole pieces are generally centrally apertured to permit insertion of the tube, and, being apertured, some of the magnetic lines of force tend to "leak" through the aperture and, unless restricted or controlled, interfere with the electrostatic convergence of the electrons in the region between the pole piece and the cathode. It is accordingly one of the objects of this invention to provide means for controlling the pattern of distribution of magnetic lines of force which leak through the pole piece aperture adjacent the electron gun.

Ideally, it would be preferable to control the leaking magnetic lines of force in a manner to produce magnetic convergence of the electrons by an amount equal to the electrostatic convergence thereof and in substantially identical patterns of distribution. It is therefore another object of this invention to provide means associated with

the electron gun and magnetic frame cooperating so as to cause the pattern of distribution of the magnetic lines of force to coincide with the trajectories of the electrons as controlled by the electrostatic convergence field.

It has been found that the pattern of distribution of the magnetic lines of force between the electron gun and the pole piece may be controlled by the size of the aperture in the pole piece, the association of magnetic means with the electron gun, and the transverse and axial interrelationship of pole piece aperture with the magnetic means. It is therefore another object of this invention to provide means for establishing a cooperative transverse and axial relationship between the pole piece aperture and magnetic means associated with the electron gun so as to adjustably control the pattern of distribution of the magnetic lines of force.

The use of high perveance electron beams results in the necessity of the collector electrode dissipating a great deal of power. Such continuous dissipation of power by the collector electrode often results in the electrode being damaged. Such damage may take the form of corrosion on the exterior surfaces of the electrode structure, which is usually provided with a multiplicity of passageways in the form of spiral grooves around its outer periphery to permit the passage of a coolant fluid. Accumulation of foreign matter in these spiral grooves as a result of such corrosion tends to plug the passages, cause vaporization of fluid coolants, and thereby reduce the efficiency of the collector to dissipate heat. It is therefore another object of the invention to provide a beam tube equipped with a detachable collector electrode water jacket permitting detachment of the jacket to repair or clean the collector electrode.

In the operation of beam tubes such as klystrons and traveling wave tubes which utilize a magnetic field to confine the electron beam, it is important that the main magnetic circuit provide only a single gap corresponding in length and placement to the path followed by the electron beam. For maximum concentration of the magnetic field in this gap, it is desirable that the remainder of the magnetic lines of force be contained within a low reluctance path composed of soft ferromagnetic material. In a structure where the axially spaced pole pieces are annular, such a low reluctance path would ideally take the form of a ferromagnetic cylinder extending between the pole pieces. However, since such an enclosure would prevent access to the tube and related structure within the frame, it has been found that apertures must be provided in such a cylinder. Such apertures disturb the magnetic field distribution and provide areas from which the magnetic lines of force may leak. It is therefore another object of the invention to provide a magnetic frame having means for selectively covering and uncovering such apertures in a magnetic frame to give convenient access to the interior of the frame while providing a low reluctance path for magnetic flux.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be apparent from the following description and drawings. It is to be understood, however, that the invention is not limited to the embodiment described and illustrated in the drawings, but may be variously embodied within the scope of the claims.

Broadly considered, the invention comprises an electron tube and magnetic circuitry therefor, both the tube and circuitry embodying novel elements cooperating to increase the operating stability and output efficiency of the apparatus. The beam tube chosen for illustration comprises a klystron tube having an electron gun, a radio frequency interaction section including resonant cavities, and a collector electrode for collecting the beam of electrons projected through the tube for interaction with the cavities.

This tube assembly, including the resonant cavities, even where these are of the external type, is inserted through centrally disposed and axially aligned apertures in spaced magnetic pole pieces having their outer peripheral portions connected by ferromagnetic means such as spaced posts and/or plates to form a magnetic frame. These posts and plates form a low reluctance path for the magnetic flux generated by appropriate magnetic coils supported on the frame. Energizing the coils establishes a strong tubular magnetic field between the pole pieces coaxially disposed with respect to the pole piece apertures. Such magnetic tube is utilized to counteract the space charge effect of the electrons forming the beam, and it is important that the tube of magnetic flux be coaxially aligned with the electron tube axis and the electron beam projected therethrough.

Since the tube structure possesses an appreciable diameter and passes through and extends on opposite sides of at least the pole piece adjacent the electron gun, the diameter of the apertures in the pole pieces is determined by the diameter of the structure which must pass therethrough. This results in the aperture in the pole piece adjacent the electron gun having an appreciable diameter, which gives rise to considerable leakage of magnetic flux into the region surrounding the aperture and lying between the pole piece and the electron gun.

It has been found that uncontrolled distribution of such magnetic flux disrupts the trajectories of the electrons in this critical region and increases the percentage of electrons striking the tube body. On the other hand, when the pattern of distribution of the magnetic flux in this region is made to closely conform to the ideal trajectories of the electrons as determined by the electrostatic field established by the beam forming electrodes, it has been discovered that almost 100% of the electrons traverse the distance between gun and collector without impinging on the tube structure. This result is due in part to elimination of radial velocities imposed on the electrons by the disrupting influence of the uncontrolled magnetic flux in this critical region, and in part by the ability to compensate for inadvertent misalignments of the beam with the surrounding structure. It has been found that for a given size drift tube, closer control over the "scalloping" tendencies of the beam permits utilization of a larger beam diameter with attendant advantages.

The invention in one of its aspects therefore comprises the conception of method and means for causing the magnetic flux in the region between the electron gun and the adjacent pole pieces to assume a pattern of distribution conforming to the trajectories of the electrons in this region. The method utilized involves securing termination of the magnetic leakage flux in a region adjacent the cathode so as to produce threading of the cathode by lines of magnetic force arranged in a pattern conforming to the ideal trajectories of the electrons. In terms of structural relationships, the method is accomplished by providing an adjustable magnetic lens including an auxiliary pole piece in close association with the cathode, and a pole piece extension adjustably mounted in respect to the auxiliary pole piece, to enable lateral displacement of the leakage flux axis to align the electron trajectories with the tube axis. The pole piece extension determines the ultimate size of the pole piece aperture and the quantum of magnetic flux leakage, and size and placement of the inner periphery of the pole piece extension cooperate with the auxiliary pole piece to control the pattern of distribution and transverse displacement of the magnetic leakage flux in the gap between the auxiliary pole piece and the adjustable pole piece extension, and to provide means for aligning the beam with the main magnetic field, which is itself centered or aligned with the tube structure. Means are also provided independent of the adjustable pole piece extension for mechanically supporting the tube coaxially with the magnetic frame.

In another of its aspects, the invention involves the provision of magnetic frame means forming a low reluctance path for magnetic flux through the magnetic frame while permitting convenient access to the interior of the frame from outside thereof. Such means comprises a magnetic frame having sections forming a substantially complete enclosure about the magnetic coils, and provided with access apertures therein selectively covered or uncovered by appropriate door means forming a part of the magnetic frame enclosure. Such enclosure ensures that the beam-confining magnetic field will be of optimum effectiveness, and that a maximum percentage of beam electrons reach the collector.

Such energy as remains in the beam after passage through the interaction section is converted into heat and dissipated by the collector. The collector preferably comprises a hollow metallic block the interior of which communicates hermetically with the interior of the interaction section. A multiplicity of passageways formed in the outer periphery of the collector block cooperate with a shell fitted therearound in a fluid-tight manner and a detachable jacket having appropriate inlet and outlet means to guide the flow of a fluid coolant about the collector.

Referring to the drawings:

FIGURE 1 is an elevational view illustrating in greatly reduced scale the beam tube and magnetic circuit therefor.

FIGURE 2 is a plan view of the apparatus illustrated in FIGURE 1, portions being broken away to reveal the underlying structure enabling centering or transverse adjustment of the pole piece extension on the frame, and the doors giving access to the interior of the frame.

FIGURE 3 is a vertical sectional view taken in the plane indicated by the line 3—3 in FIGURE 2, and illustrating the inter-relationship of the auxiliary pole piece and main pole piece extension forming the magnetic lens according to this invention.

FIGURE 4 is a vertical sectional view taken in the plane indicated by the line 4—4 in FIGURE 1, and illustrating the inter-relationship of collector, collector water jacket and lower pole piece.

FIGURE 5 is a schematic view illustrating the approximate pattern of distribution of magnetic lines of force in a conventional klystron.

FIGURE 6 is a schematic view illustrating the effect on the pattern of distribution of the magnetic lines of force of orienting an auxiliary magnetic pole piece adjacent the cathode.

FIGURE 7 is a view similar to FIGURE 6 and illustrating the effect on the pattern of distribution of the magnetic lines of force of the cooperation between the auxiliary magnetic pole piece and the adjustable pole piece extension.

In more specific detail, and referring particularly to the drawings, the operation of a klystron amplifier necessitates projection of an elongated beam of electrons between the generating source of electrons and a collector thereof. Between its point of generation and its point of collection, the electron beam interacts with a radio frequency interaction structure in a manner to amplify radio frequency signals. Such interaction structures are often quite long, and impose the problem of preventing the electron beam from dispersing in the area between its point of generation and point of collection due to the inherent space charge effect. To prevent such dispersion of the electrons of the beam, electron beam tubes are commonly supported in a magnetic structure or frame which cooperates with magnetic field producing coils to confine the electron beam along a predetermined axis. In spite of the magnetic field, however, there is a tendency for the space charge effect inherent in the electron beam to cause the electrons of the beam to disperse radially outwardly under the impetus of a radial velocity component. This tendency is balanced by the magnetic field force; however, if such confinement or balancing is not ideal, an undulating or scalloped configuration of the beam results. Such scalloping of the beam is undesirable because it causes electrons near the outer periphery of the beam to impinge against related tube structure.

Attempts have been made to control such scalloping of the electron beam by means of auxiliary magnetic coils interposed between the main magnetic field and the source of the electron beam. Such a structure is disclosed and claimed in United States Patent 2,867,746, assigned to the assignee of the present invention. As described in that patent, the purpose of the auxiliary coil is to establish an auxiliary magnetic field through which the beam must pass before entering the main magnetic field, so as to precisely guide the electron beam into the main magnetic field. It was thought that if the beam were guided into the main magnetic field so that the axis of the beam and the axis of the main magnetic field coincided very closely, such scalloping of the electron beam in the main magnetic field would be obviated. It has been found that such scalloping of the beam still occurs; however, not to such an extent as without the auxiliary magnetic coil.

It has been discovered that one way to prevent such scalloping of the beam is to allow a portion of the main magnetic field to project in a controlled manner between the main field and the generating source of electrons. In other words, it has been found that when the lines of magnetic force in this region closely coincide or match the trajectories of the electrons emanating from the source and being converged by the electrostatic means, the electrons will not have a radial velocity component imposed on them, and they will therefore not have the tendency to scallop as they proceed through the magnetic conduit formed by the main magnetic field. In a tube recently manufactured according to this invention, a test showed that over 99% of the electron beam was passing through the interaction structure without impinging thereon.

The invention as embodied with respect to a klystron amplifier tube, by way of example, comprises an electron gun **2** integrally and hermetically connected to one end of the radio frequency interaction section **3**, including resonant cavities **4**, and a collector electrode **6** integrally and hermetically connected to the end of the radio frequency section remote from the electron gun. The resonant cavities **4**, including drift tube portions **7** and interaction gaps **8**, interact with the beam in a well known manner for klystron tubes.

As shown in FIGURES 1 and 2, the tube so constituted, with resonators attached, is suspended or otherwise supported in a magnetic frame **9**. The magnetic frame comprises upper and lower pole pieces **12** and **13**, respectively, each conveniently fabricated from a substantially rectangular plate of magnetic material, and provided with large central apertures **14** and **16**, respectively. The pole pieces **12** and **13** are held in spaced parallel relation by a plurality of columns or posts **17** interposed between the pole pieces and connected thereto adjacent the outer peripheries thereof. The interconnection between the pole pieces and the columns or posts is preferably a detachable one, but one providing a low reluctance path for the flow of magnetic flux lines therebetween. Mounted on pole piece **13** in close association to aperture **16** therethrough is an axially extending cylindrical support **19** secured at one end to the pole piece. When the tube is assembled in the magnetic frame, the tube is lowered into the frame from above with the collector at the lower end of the tube. The collector passes through tubular support **19**, and the upper end of the tubular support is adapted to engage a projection or abutment on the tube body so as to rigidly support the tube in the frame. In this position, the interaction section of the klystron lies spaced between axially spaced pole pieces **12** and **13**, and electron gun **2** extends on the opposite side of pole piece **12**, but closely adjacent thereto.

To coaxially align the tube with the apertures in pole pieces **12** and **13**, pole piece portion **12** is provided with a pole piece extension **18** (FIGURE 2) which preferably comprises an annular steel plate having its outer peripheral portion **20** detachably secured adjacent the inner periphery **21** of pole piece portion **12**. Such interconnection is conveniently effected by means of thumb screws **22**. As shown in FIGURE 2, pole piece extension **18** is preferably formed in two semi-circular parts which, when corresponding edges are abutted, form a complete annulus about the axis of the tube. Formation of the pole piece extension in two parts is necessary because the inner peripheral edge **23** of the extension is smaller in diameter than the outside diameter of the electron gun closely adjacent thereto. The inner peripheral edge portion **23** of the pole piece extension is preferably rabbeted, and provides a seat for peripheral edge portion **26** of brass insert **27**, the inner periphery **28** of which lies closely about neck **29** of the tube. In order to insert the brass insert about the neck of the tube, the insert is preferably split diametrically into two sections as with pole piece extension **18**. From this it will be seen that elements **12**, **18** and **27** coact to retain the upper end of the tube coaxially aligned with the tubular support on the lower pole piece **13**.

In order to energize the magnetic frame, and provide a confining magnetic field for the beam which is projected through the tube, a plurality of coils **31** are provided supported on columns or posts **17**. Suitable cantilever support braces **32** adjustably mounted on each of the posts **17** underlie the coils and provide support therefor. The coils are of course arranged coaxially about the axis of the tube. When the coils are energized, magnetic flux is caused to permeate the magnetic members of the frame, including the pole pieces and the support posts. It has been found, however, that to provide four spaced posts is not sufficient to confine the magnetic flux, and that therefore the strength of the field in the gap which corresponds to the space between the pole pieces is not as strong as it would otherwise be. In order, therefore, to provide a low reluctance path, I have found that the provision of pivotally mounted doors **33** extending between the upper and lower pole pieces functions both to provide a low reluctance magnetic path between the pole pieces, in addition to the posts, and provides selective access to the interior of the frame. Of course, doors may be placed on all four sides of the frame to provide easy access thereinto from any direction.

As thus far described, it will be noted that when the magnetic frame is energized, a magnetic field will be provided in the gap between the inner periphery **23** of pole piece extension **18**, and the tubular support mounted on lower pole piece **13**. The configuration of this field will be largely controlled by the size of the apertures in pole piece extension **18** and tubular support **19**. In the region of pole piece extension **18**, it has been found that the magnetic field will leak into the region between the electron gun and the main magnetic pole piece. Such leakage will take the approximate pattern shown in FIGURE 5, in which the magnetic lines of force thread the cathode substantially parallel to the axis of the tube. It will readily be seen that such pattern of distribution of the magnetic flux lines above the pole piece does not match or correspond to the trajectories of electrons in this region. Such absence of correspondence in the pattern of distribution between the electron trajectories and the magnetic field lines results in a radial velocity component being imposed on the converging electrons, which results further in the ultimate beam configuration being scalloped. I have found that such pattern of distribution of the magnetic lines of force may be controlled and made to conform more closely to the trajectories of the electrons by the interposition of an auxiliary ferromagnetic pole piece **41** placed in close proximity to the cathode and focus electrode of the electron gun. This arrangement is shown schematically in FIGURE 6. To more closely control the pattern of distribution of the magnetic lines of force, it has been found that in addition to auxiliary pole piece 41 associated with the electron gun, it is preferable to also provide an adjustable auxiliary pole piece extension 42 movably supported on magnetic pole piece extension 18 adjacent its inner periphery, and formed from a pair of complementary plates, the inner arcuate edge portions of which overlap the outer edge portion of brass insert 27 to lock the brass plate in position. By correlating the inner diameter and placement of adjustable pole piece extension 42 with the diameter and placement of auxiliary pole piece 41 associated with the electron gun, substantially exact conformance or distribution of the magnetic lines of force 43 with the trajectories of electrons 44 is achieved, as shown in FIGURE 7.

This construction, embodied in a practical structure, is shown in FIGURE 3 and comprises electron gun 2 having a metallic base plate 46, to which is hermetically united one end of a cylindrical dielectric shell 47. On the end of dielectric shell 47 remote from base plate 46, the structure incorporates a radially inwardly extending plate 48 having a large central aperture 49, and adapted to adjustably support detachably, adjacent its inner periphery, a modulating anode 51. Adjustability of the modulating anode is important because it allows exact alignment of the aperture therein with the cathode and focus electrode. On the side of annular plate 48 opposite the tubular dielectric shell 47, a second tubular dielectric envelope portion 52 is provided, having its end remote from plate 48 integrally and hermetically united to the interaction section of the tube.

Within tubular dielectric envelope portion 47 is detachably mounted a metallic support shell 53 having a cylindrical portion 54 and a conical base portion 56. A flange 57 on the conical base portion is suitably attached to base 46 by screws 58. Extending from cylindrical portion 54 is a support shell extension 59, one end of which is spot welded to cylindrical portion 54, and the other end of which is provided with a conical section 61 and an integral cylindrical extension 62 spot welded to the peripheral edge of cathode 63. The diameter of the cathode is somewhate smaller than the diameter of shell extension 59, and is thermally shielded therefrom by auxiliary shell 64 extending from the peripheral edge of the cathode. The other end of shell 64 is appropriately spot welded to the peripheral edge of a transversely extending heat shield disk 66. This disk is preferably concave in form so as to direct heat back toward the cathode, and cooperates with other transversely extending heat shields to support the heater coil 67 in heat transfer relation with the cathode. Suitable leads 68 and 69 connect opposite ends of the heater coils to an appropriate source of power outside the envelope.

Spot welded to one end portion of shell extension 59 is a focus electrode support cylinder 71 having a plurality of apertures 72 thereon to reduce the amount of metal through which heat may be conducted to the focus electrode. Adjacent one end of cylindrical support 71 is provided a focus electrode having an intermediate portion 73 spot welded to the end portion of shell 71, and having a conically tapered portion 74 extending into close proximity to the outer periphery of the cathode. The spacing between the adjacent edges of the focus electrode and cathode is preferably in the range of .020″, while the free end of the focus electrode is provided with a rolled-over edge portion 76 as shown. In operation of the electron gun, it has been found that while the apertures is in the focus electrode support render the support shell an efficient heat dam, they also permit the radiation of heat therethrough, and unless prevented, such radiation would heat cylinder 47 excessively. Therefore, in order to intercept such radiation, I provide an auxiliary cylindrical heat shield 77 surrounding the focus electrode and shell 59 in the region of the apertures 72, and having one end spot welded to shell 59. The other end of cylinder 77 is free to permit thermal expansion and contraction without danger of stressing or straining related structure as a result thereof. This amount of expansion and contraction is minimal, however, because of the nature of support shell 71, and because of the interception of heat by shell 77 and its conductance back to shell 59.

Mounted on shell 53 adjacent the union between conical portion 56 and cylindrical portion 54, is a radially extending annular plate 78 welded at its inner periphery to cylindrical shell 54. Plate 78 serves to detachably support the flanged end 79 of an auxiliary pole piece 81. Pole piece 81 is fabricated from ferromagnetic material preferably in a hollow cylindrical conformation closely surrounding support shell 59, and at one end extending under the rolled-over edge portion 76 of the focus electrode. This end of the auxiliary pole piece is therefore securely held by the focus electrode, while the other end is detachably connected to support plate 78. It will of course be apparent that auxiliary pole piece 81 in FIGURE 3 corresponds to the same element shown schematically in FIGURES 6 and 7 and designated by the reference number 41. As shown in FIGURE 3, auxiliary pole piece 81 extends on both sides of the cathode. In operation, therefore, when the magnetic circuit is energized, the magnetic field leaks through the aperture in pole piece extension 18, and many of the magnetic lines of force terminate on auxiliary pole piece 81. In being so forced out of their natural pattern of distribution, the magnetic field lines are caused to closely align themselves with the trajectories of the electrons emanating from the cathode. This correspondence is selectively controlled and increased by the movable plate 42, which may be adjusted at will into a desired correlation with auxiliary pole piece 81 to control the passage of the beam into the drift tube.

In the commercial production of electron guns of the type shown, failure to adhere to manufacturing tolerances may result in the electron beam not being axially aligned with the axis of the drift tubes. This results in a large number of electrons impinging against the interior surfaces thereof, thus raising the temperature of the electron tube and also the body current of the klystron. By monitoring either or both these effects, the accuracy of alignment of the beam with the tube structure may be determined. It has been found that with the adjustable magnetic lens described above it is possible to closely adjust the convergence of the electron beam and its scalloping tendencies due to space charge effects so that substantially the entire beam passes through the drift tube without impinging on the interior surfaces thereof. Such accuracy in causing the electron beam to become aligned with and to be projected through the drift tube results in less critical and time consuming tuning of the apparatus to minimize "scalloping" of the beam, the presence of which results in operating instability.

The energy remaining in the beam after passage through the interaction structure is dissipated as heat which is conventionally effected by causing coolant fluid to flow over the collector surfaces. To effect a more efficient transfer of heat between the circulating coolant and the collector block, it is common practice to provide a block with a plurality of spiral grooves around the outer periphery thereof. A thin shell normally brazed over the lands which are formed between the grooves channels the coolant fluid through the grooves over the entire length of the collector, until it exits through an outlet aperture. This construction results in the inability to remove foreign matter from the grooves to maintain sufficient heat transfer. With time the collector therefore loses its efficiency to dissipate heat.

In the construction illustrated in FIGURE 4, this problem has been obviated by providing a collector block 86 with a multiplicity of spiral channels 87 over which is detachably mounted a shell 88, secured as by means of one or more screws 89 at one end thereof. The shell at its end remote from the interaction section of the tube is provided with a conical portion 91 having an open truncated apex end 92 lying closely adjacent closed end 93 of the collector block. Encircled about shell 88 at the intersection of the conical portion 91 and cylindrical portion 88 is an O-ring bracket 94. The O-ring bracket is brazed to shell 88, and is provided in its outer peripheral surface with an annular groove 96 adapted to receive a rubber O-ring 97. The open end of the collector block is provided with a radially extending mounting flange 98, having in one surface thereof an annular channel 99 adapted to receive a second O-ring 101. The collector block assembly is inserted into hollow collector jacket shell 102 having an open end 103 and a closed end 104. The open end of collector shell 102 is provided with a radially outwardly extending flange 106 having apertures 107 therein.

When assembled with the collector block assembly, flange 106 abuts mounting flange 98. Such abutment has the effect of compressing and sealably deforming O-ring 101 between the two flanges which are then retained in sealed relation by cap screws 108. In the assembly of shell 88 within the jacket 102, O-ring 97 seated in its channel lies sealingly interposed between the two shells and serves to coaxially space the shells with relation to each other. The O-ring also lies spaced axially between inlet and outlet apertures 109 and 112, respectively, in shell 102 and serves as a fluid-tight baffle to guide coolant fluid first through aperture 92 in the apex end of conical portion 91 of shell 88. The inlet and outlet apertures 109 and 112 are provided with suitable fittings 113 for connection to appropriate conduits.

It will thus be seen that coolant entering aperture 109 fills the chamber 114 between conical portion 91 and shell 102. From this chamber it progresses through aperture 92 and flows around the collector end 93, and progresses through spiral passages 87 to the upper end of the collector. The coolant then spills out of the spiral channels 87 into the space between shell 88 and jacket 102 and exits through outlet aperture 112. It will thus be apparent that when it becomes necessary to clean the grooves or spiral channels in the collector block, cap screws 108 may be removed and the outer jacket 102 detached from the collector block assembly. Next, screws 89 are removed and the cylindrical shell 88 is slipped from the collector block, thus exposing the channels 87 which may then be cleaned in any appropriate manner. Such facility to clean the coolant passages ensures that the efficiency of the collector to dissipate heat will be maintained for the life of the tube.

I claim:

1. Electron beam generating apparatus comprising a beam tube having an electron gun including an energizable cathode and anode to project and accelerate a beam of electrons and a collector electrode to intercept the beam, a magnetic frame about the tube between the electron gun and collector having first and second apertured ferromagnetic pole pieces adjacent the electron gun and collector, respectively, and including magnetic means establishing lines of magnetic force between the cathode and said first pole piece, means associated with the electron gun on the side of said anode remote from said first apertured pole piece and cooperating with said first apertured pole piece to control the pattern of distribution of said lines of magnetic force, and said first apertured pole piece comprising a first portion fixed with respect to the tube and a second portion selectively movable with respect to said means associated with the electron gun.

2. The combination according to claim 1, in which said means associated with the electron gun comprises a tubular auxiliary pole piece and said second portion of the first pole piece comprises an apertured plate extending transverse to the axis of said tubular auxiliary pole piece.

3. The combination according to claim 1, in which non-ferromagnetic means are detachably interposed between said first ferromagnetic pole piece and the tube to retain the tube coaxially arranged with respect to the frame.

4. In a beam tube having an interaction section, an electron gun comprising a tubular dielectric envelope portion, an end plate hermetically closing one end of the tubular dielectric envelope portion, beam forming electrodes supported within the envelope portion and including an energizable cathode and focus electrode, an accelerating anode supported on the end of said dielectric envelope portion remote from said end plate, and a body of ferromagnetic material within the envelope portion closely adjacent said cathode and focus electrode, said body of ferromagnetic material being separated from said accelerating anode and located between said accelerating anode and said end plate, said end plate constituting a base plate, and said cathode and focus electrode being detachably supported on the base plate.

5. The combination according to claim 4, in which said ferromagnetic body comprises a tube closely surrounding the cathode and focus electrode.

6. In an electron tube, a collector assembly comprising a hollow metallic collector block, a hollow outer shell closed at one end and open at the other end, threaded clamp means detachably holding said outer shell, arranged about the collector block in radially spaced relation thereto, an inner shell open at both ends arranged about the collector block threaded clamp means detachably connecting said inner shell to said collector block, the open ends of the inner shell communicating the interior of the inner shell with the interior of the hollow outer shell, and means interposed between the collector block and inner shell and between the inner shell and hollow outer shell cooperating with said shells to define inlet and outlet passages for circulation of a fluid coolant about said collector block.

7. The combination according to claim 6, in which said means interposed between the collector block and inner shell comprises a plurality of splines integral with the collector block.

8. The combination according to claim 6, in which said means interposed between the inner and outer shells includes a fluid-tight seal ring fixed intermediate the ends of the inner and outer shells.

9. Electron beam generating apparatus comprising in combination a beam tube having an electron gun including a cathode and a heater therefor, a focus electrode, and an anode providing an electrostatic convergence field to project, converge and accelerate a beam of electrons, a collector spaced along the beam axis from said gun to intercept said beam of electrons, an electron beam interaction section positioned between said anode and said collector, magnetic circuit generating means for said beam apparatus, said magnetic generating means comprising magnetic coil means and magnetic field guiding frame means including a first apertured magnetic pole piece positioned adjacent said gun between said gun and said collector and spaced a substantial distance from said cathode toward said collector, a second magnetic pole piece adjacent said collector, and magnetic conductor means interconnecting said pole pieces, said magnetic circuit generating means being located entirely on the collector side of said gun whereby substantially the only magnetic field in the cathode region is the stray field which emanates from the aperture in said first pole piece, and field shaping means for shaping said stray field to coincide with the trajectory of electrons leaving said cathode under the direction of said convergence field, said field shaping means comprising a cylinder of magnetic material surrounding said cathode and spaced from said magnetic

circuit generating means, said shaping cylinder extending a substantial distance from said cathode toward said anode and terminating in spaced relation to said anode, said magnetic field shaping means being located entirely outside the space between said cathode and said heater, a non-magnetic hermetically sealed envelope wall around said cathode, and said shaping cylinder being positioned inside said envelope wall.

10. A frame constituting a magnetic circuit for beam tubes comprising a pair of axially spaced centrally apertured pole pieces through which a beam tube may extend, a plurality of ferromagnetic posts extending between outer peripheral portions of said pole pieces and forming a part of the magnetic circuit, a plurality of energizable coils detachably supported on said posts and adjustable into coaxial alignment with said pole piece apertures to establish a magnetic field therebetween when said coils are energized, and a multiplicity of plates of ferromagnetic material extending lengthwise between and magnetically interconnecting said pole pieces to normally enclose the frame and coils, at least one of said plates being pivotally mounted for movement to give access to the interior of the frame.

11. The combination according to claim **10**, in which one of said pole pieces includes a first portion fixed with respect to said posts and a second portion constituting an extension of said first pole piece portion and selectively movable thereon to transversely adjust the location of the pole piece aperture with respect to said beam tube.

References Cited by the Examiner

UNITED STATES PATENTS

2,608,668	8/1952	Himes	315—3.5 X
2,687,490	8/1954	Rich et al.	315—5.38
2,829,299	4/1958	Beck	315—3.5
2,879,440	3/1959	Abraham et al.	315—5.38
2,909,691	10/1959	Heil	315—5.38 X
2,928,972	3/1960	Nelson	315—5.38
2,936,394	5/1960	Brewes	315—3.5
2,991,391	7/1961	Beaver	315—5.38
3,104,338	9/1963	Symons	315—5.38 X
3,155,866	11/1964	Poole	315—3.5

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