Sept. 26, 1967 M. E. LEVIN 3,344,306

KLYSTRON HAVING TEMPERATURE MODIFYING MEANS FOR THE ELECTRODES THEREIN AND THE FOCUSING MAGNETIC CIRCUIT

Filed March 26, 1962 3 Sheets-Sheet 1

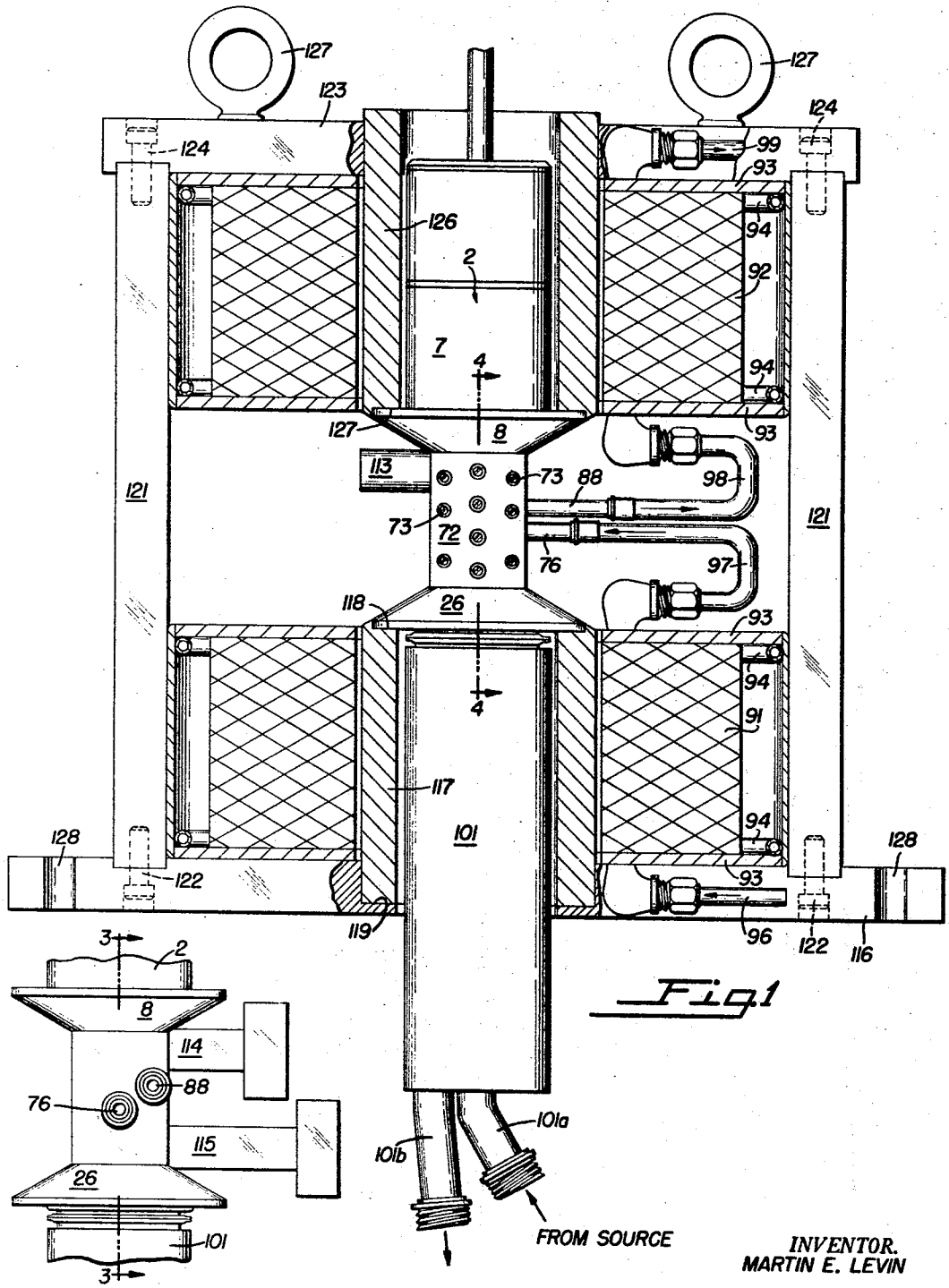



Fig. 1




Fig. 2

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Filed March 26, 1962 3 Sheets-Sheet 2

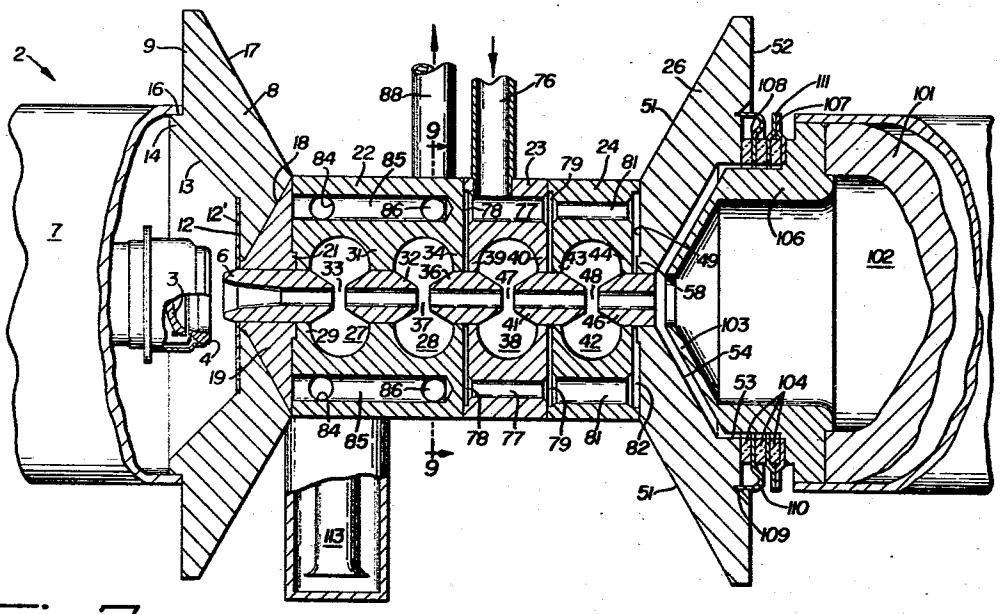


Fig. 3

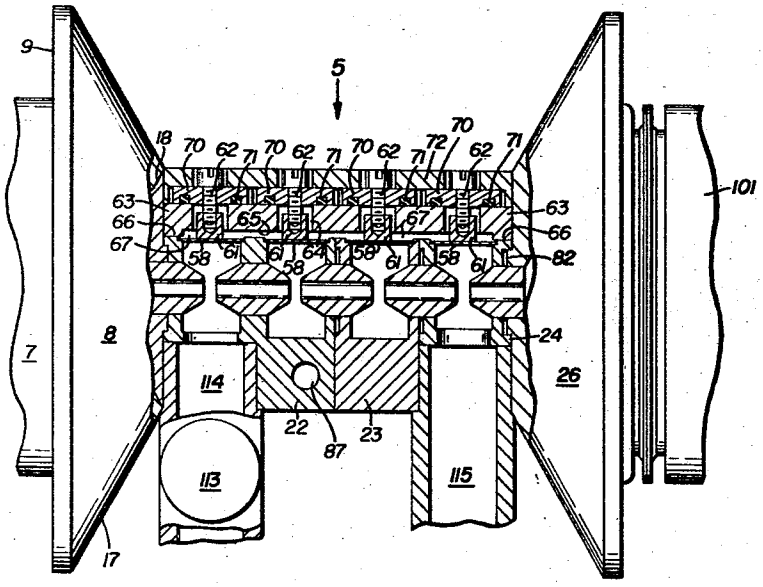


Fig. 4

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Filed March 26, 1962 3 Sheets-Sheet 3

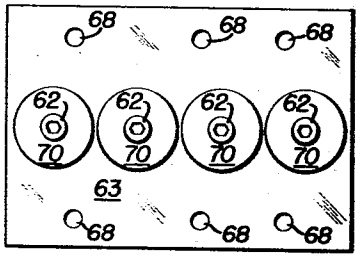



Fig. 5

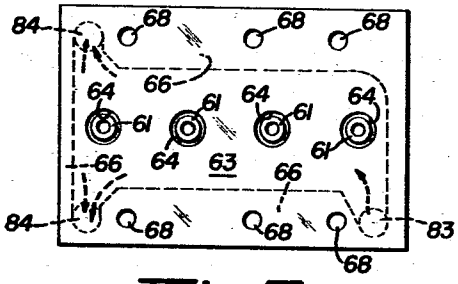



Fig. 6

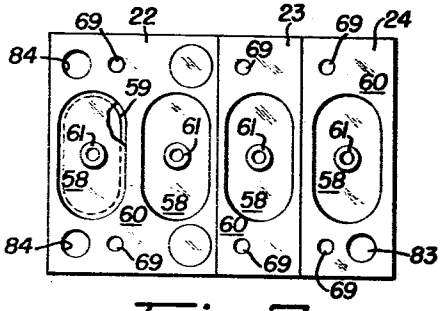



Fig. 7

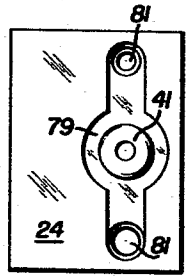



Fig. 8

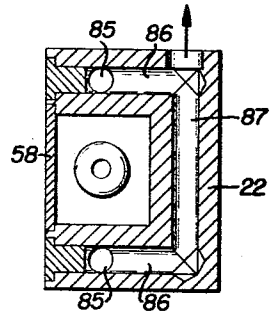



Fig. 9

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3,344,306

# KLYSTRON HAVING TEMPERATURE MODIFYING MEANS FOR THE ELECTRODES THEREIN AND THE FOCUSING MAGNETIC CIRCUIT

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Filed Mar. 26, 1962, Ser. No. 182,197
8 Claims. (Cl. 315—5.39)

This invention relates to an integral cavity beam tube, and more particularly to a klystron amplifier designed to operate in X-band, at a frequency between 7.125 and 8.5 gigacycles, with more than 20 kilowatts continuous wave power output.

In high power klystron amplifiers designed to operate in X-band, one of the most difficult problems encountered is the dissipation of heat from the radio-frequency interaction section while maintaining the resonant cavities of the requisite size and spacing to operate at or near the design frequency. For instance, in the klystron amplifier forming the subject matter of this invention, the radio-frequency interaction section is about the size of a cigarette package and is designed to operate at about 7.5 kmc. with little or no frequency drift. It is therefore one of the important objects of this invention to provide cooling means for such a radio-frequency interaction section so as to minimize frequency drift due to thermal expansion and displacement of the cavities.

It has been found that in a radio-frequency interaction section of the small size required for operation in X-band, the portions of the structure most susceptible to heating are the drift tubes enclosed within the body and closely surrounding the electron beam. It has heretofore been the practice to fabricate the radio-frequency structure for X-band klystrons from a single block of material, such as copper. Such practice, however, precludes the efficient transfer of heat away from the drift tube sections and R-F cavities, and it is accordingly another important object of the present invention to provide a radio-frequency section for an X-band klystron amplifier fabricated in a manner to permit more efficient cooling of those drift tube sections and R-F body sections most susceptible to heating.

In the operation of a klystron amplifier of any type, operating at any frequency, it is desirable that there be minimum interception of the electron beam by the surrounding radio-frequency structure. The extent to which such minimum interception may be achieved is dependent in part upon the accuracy with which the tube components are fabricated, the accuracy with which such components are aligned in the finished tube, and the extent to which the electron beam is confined to the axis of the drift tubes. In a klystron amplifier operating in X-band, these features are difficult of achievement because of the small size. Furthermore, the achievement of these features is especially important in a tube such as the one described due to the very high power density in the beam and the likelihood of melting the drift tubes by impingement of the beam thereon. It is accordingly an additional object of the invention to provide a structure which enables substantially 100% beam transmission from electron gun to collector.

In the fabrication of an electron tube such as the one herein described for operation in X-band, it is the practice to fabricate the tube in sections such as a collector section, a radio-frequency section, and a gun section. The sections are separately fabricated, and then joined to form a composite structure. A serious problem of alignment is presented by the necessity of aligning the electron gun and beam trajectory with the bore through the drift tube of



the radio-frequency section. Misalignment will of course result in interception of the beam by the radio-frequency structure and cause heating. It is therefore a still further object of the invention to provide means by which the electron gun section and the radio-frequency section may be aligned for substantially 100% transmission of the electron beam through the radio-frequency section.

Part of the problem of beam transmission through the radio-frequency structure involves the relationship between the tube and the magnetic frame or magnetic means associated with the tube and radial confinement of the electron beam in the region between the electron gun and the collector. It is therefore another object of the invention to provide a magnetic circuit, portions of which form a part of the tube envelope and are fabricated therewith to ensure accurate alignment of the electron beam and radial confinement thereof as it passes through the radio-frequency structure.

It is generally desirable in any tube that some means of limited tuning of the resonant cavities be provided. In klystron tubes designed to operate at lower than X-band frequencies, this is conveniently done by providing a displaceable flexible wall forming one side of the resonant cavity. This is usually effected by a corrugated diaphragm or bellows in tubes that permit a relatively long excursion for such displaceable members. At X-band, however, a very small movement of such a flexible wall member results in a relatively large frequency shift. Any tuning mechanism used for an X-band tube must therefore be sufficiently rigid to prevent undesirable frequency variations due to uncontrolled movement of the deformable member, as from vibration, but must also be designed to permit a limited amount of controlled flexure of the tuning member when desired.

In this regard it should be noted that another source of heat in a resonant cavity arises from the "skin resistance" to circulating R-F currents, and that heat from this source is particularly aggravated because of the high frequency and small dimensions involved. In the present tube, for instance, the R-F losses are in the order of from 400 to 700 watts, while power losses due to beam interference, despite the substantially 100% beam transmission, amount to about 500 to 800 watts. Any kind of a tuning mechanism which causes perturbation and/or distortion of the cavity tends to increase heating of the R-F body due to R-F losses. It is accordingly a still further object of the invention to provide a novel tuning means for an X-band resonant cavity, the tuning means being of a nature possessing the requisite flexibility to provide the desired tuning range, the requisite rigidity to prevent movement due to vibration, and a configuration tending to minimize perturbation and/or distortion of the cavtity.

Another object of the invention is to provide means for cooling such tuning means.

A still further object of the invention is to provide a fluid cooling system for a multicavity klystron wherein a multiplicity of fluid "jackets" within the klystron body are connected in parallel to a single source of fluid coolant, the fluid egressing from these "jackets" being recombined and passing in series connection through a tuner chamber, from which the coolant again divides into parallel paths to cool other parts of the body, and is then recombined and egresses from the tube body.

A still further object of the invention is to provide a cooling system for a klystron apparatus in which the cooling passages for the body are connected in series with the cooling passages for the magnetic coils, and this combination in turn is connected in parallel with the collector cooling system.

The invention possesses other objects and features of value, some of which, with the foregoing, will be apparent

from the following description and the drawings. It is to be understood, however, that the invention is not limited to the particular embodiment of method or means illustrated and/or described, but may be embodied in a plurality of forms within the scope of the appended claims.

Broadly considered, the klystron amplifier of the present invention comprises an electron gun section, a radio-frequency interaction section, and a collector section axially aligned and hermetically interconnected to provide an evacuated envelope. The electron gun section is connected to the radio-frequency interaction section by the interposition of a first ferromagnetic pole piece which forms part of the evacuated envelope, while the collector section is connected to the opposite end of the radio-frequency interaction section by a substantially similar second ferromagnetic pole piece which also forms part of the evacuated envelope. Rigidly interposed between the axially spaced ferromagnetic pole pieces, the rigid multi-cavity radio-frequency interaction or body section includes a plurality of drift tube sections defining interaction gaps in the cavities. The radio-frequency interaction section is fabricated to provide a limited amount of tunability for each of he cavities, and in addition is fabricated to provide efficient fluid cooling of each of the cavities and the drift tube sections.

It has been found that when radio-frequency structures are properly fluid cooled, the tubes operate at a much lower temperature and are more stable. However, because of the small size of the radio-frequency structure in a tube operating in X-band, it is difficult to provide a composite body having hollow resonant cavities therewithin, and also provided with adequate passages or "jackets" between the cavities through which a fluid coolant may pass. The difficulty of coolinga tube this size is aggravated by the inherent R-F losses which can only be minimized and not eliminated, and by the difficulty of achieving substantially 100% transmission of the electron beam through the several cavities. There are two sources of heat with which one must contend. Minimization of heat caused by beam interception is conventionally accomplished by one of three different means, namely, the use of an electromagnetic coil or plurality of such coils to produce a strong radially confining magnetic field, the use of a permanent magnet, or the use of a plurality of permanent magnets in the nature of a periodic structure to establish a magnetic field axially aligned with the drift tubes to thereby confine the electron beam projected therethrough. In a tube of this power and frequency, it has not been possible to utilize either periodic permanent magnet focusing or a single permanent magnet which would provide a magnetic field of the required strength, which for the tube described ranges between 3000 and 5000 gauss. Accordingly, a pair of axially spaced electromagnetic coils, cooperating with a generally H-shaped magnetic frame adapted to provide a magnetic circuit in conjunction with axially spaced pole pieces forming part of the tube envelope have been utilized. The magnetic circuit is designed to provide self-centering of the tube within the frame, and is provided with electromagnetic coils having fluid cooled passages therearound which connect with the cooling system of the tube. The magnetic circuit and the tube are therefore co-operatively related both mechanically and functionally to provide a compact assembly.

Referring to the drawings:

FIGURE 1 is an elevation partly in vertical section showing the tube mounted within the magnetic circuit and illustrating the interrelationship between the cooling system for the magnetic coils and the cooling system for the tube.

FIGURE 2 is an elevation taken in a direction 90° to the view illustrated in FIGURE 1. The view illustrates the relationship between the radio-frequency section and the input and output waveguide connections.

FIGURE 3 is a sectional view taken in the plane indicated by the line 3—3 of FIGURE 2, and illustrates the two parallel passages utilized in cooling the first and second cavities, and the three parallel passages utilized in cooling the penultimate and output cavity.

FIGURE 4 is a sectional view taken in the plane indicated by the line 4—4 in FIGURE 1, and illustrates the tuner assembly and "jacket" construction utilized in cooling the tuner assembly.

FIGURE 5 is an elevation of the radio-frequency body taken in the direction indicated by the arrow 5 is FIGURE 4, but with the cover plate removed to expose the arrangement of tuning screws and attached seal plate.

FIGURE 6 is a view taken in the same direction as FIGURE 5, but with the tuning screws and attached seal plates removed from the assembly and showing in dash lines the outline of the tuner "jacket."

FIGURE 7 is a plan view taken in the same direction as FIGURE 5, but with the "jacket" plate removed to expose the diaphragm tuners and illustrating the configuration and manner of attachment of the diaphragms in the tube body.

FIGURE 8 is an end view of one of the body sections, illustrating the "jacket" or coolant passage about one of the drift tubes.

FIGURE 9 is a transverse sectional view through the body of the tube taken in the plane indicated by the line 9—9 in FIGURE 3.

In terms of greater detail, the klystron amplifier of the invention comprises an electron gun section **2** (FIGURES 1 and 3) having a cathode **3**, a focus electrode **4**, and an accelerating anode **6** (FIGURE 3). The electron gun section includes an outer hollow cylindrical metallic housing **7** hermetically united at one end to a magnetizable annular pole piece **8**. As viewed in FIGURE 3, the pole piece is provided on its face adjacent the electron gun with annular flat surfaces **9** and **12** situated, respectively, adjacent the outer and inner peripheries of the pole piece. The flat surfaces **9** and **12** are radially spaced from each other and connected by an angularly disposed truncated conical surface **13** which at its apex end is intercepted by the surface **12**, and which at its base end merges with a cylindrical flange **14** extending from the surface **9** to provide a shoulder **16** about which the electron gun housing **7** is brazed. As is shown in FIGURE 3, the surface **12** of the pole piece **8** is provided with a coating or layer **12'** of copper bonded thereto as by brazing.

On its opposite face, the pole piece **8** is provided with a pair of oppositely diverging conical surfaces **17** and **18**, the outer periphery of surface **17** terminating at the outer periphery of the pole piece, and the apex end of the surface **18** terminating and defining the inner periphery of the pole piece **8**.

Filling the recess in the pole piece formed by the conical surface **18** is a solid copper plug **19**, preferably cast into position so that an inter-metallic alloying occurs between the iron pole piece and the plug **19** along the surface **18**. The copper plug is centrally bored to receive the accelerating anode **6** as shown, and is provided with a pad **21** projecting from one face thereof and adapted to fit into a complementary recess formed about the accelerating anode in the immediately adjacent radio- frequency body block **22**. Accelerating anode, pad, and recess thus cooperate to accurately position the pole piece with respect to the radio-frequency body section. The configuration of the pole piece is significant in that it controls the shape of the magnetic field, providing for controlled leakage of magnetic flux back through the cathode along lines closely matching the trajectory of the electrons between the cathode and focal point thereof.

As shown in FIGURES 3 and 4, the radio-frequency body section of the klystron is preferably fabricated from three axially aligned composite copper blocks **22**, **23** and **24**. The block **22** lies immediately adjacent and is hermetically brazed to the copper plug secured in pole piece **8**, while block **23** is sandwiched between and hermetically united to blocks **22** and **24**, the latter being hermetical-

ly united to one face of a second pole piece 26 axially spaced from pole piece 8 and in substantial alignment therewith. To ensure maximum rigidity in the construction of the body section of the klystron, each of the body blocks 22, 23 and 24 are formed from a solid block of oxygen-free high-conductivity copper, the block 22 having formed therein a pair of axially spaced resonant cavities 27 and 28. The cavity 27 is defined by end wall 29 and intervening wall 31 disposed between the two cavities. The accelerating anode 6, which also functions as a drift tube section, is integrally brazed within a central bore formed in wall 29, while a second drift tube section 32 is brazed in a central bore formed in wall 31. The adjacent ends of drift tube sections 6 and 32 are spaced apart to provide an interaction gap 33 in cavity 27. The opposite end of body block 22 is provided with end wall 34, also centrally bored to receive a drift tube section 36. An interaction gap 37 is formed between the inner ends of drift tube sections 32 and 36 within cavity 28. Some idea of the sensitivity to thermal expansion and contraction of a klystron this size, and of the necessity for efficient cooling and extreme accuracy in fabrication, will be obtained by considering that the inner diameter of each drift tube section is only about .125" and that the spacing between drift tube sections forming an interaction gap is only about .100". A tube this size is so sensitive that a variation in gap spacing of only about .001" will result in a frequency shift of 10 to 15 mc.

The radio-frequency body block 23 is provided with a single cavity 38 defined by end walls 39 and 40. Both of these walls are centrally bored, the wall 39 receiving the projecting end of the drift tube section 36, while the wall 40 is utilized to support drift tube section 41. Body block 24 is provided with a single cavity 42, defined by end walls 43 and 44, each centrally bored as corresponding walls in the other two blocks, the wall 43 receiving the projecting end of drift tube section 41 in a snug sliding fit which is subsequently brazed. Wall 44 receives drift tube section 46, which is also brazed to the iron pole piece 26. The interaction gaps 47 and 48 formed, respectively, in resonant cavities 38 and 42 are formed by the adjacent ends of drift tube sections 36 and 41 and drift tube sections 41 and 46. It should be noted that drift tube section 36 can function as an alignment boss to facilitate assembly of body block 23 with body block 22. Drift tube section 41, which projects through end wall 40 of body block 33, can also function to align body block 24 thereon. It has been found, however, that a better practice is to initially pilot bore the cavities and align them on a mandrel, after which they are brazed. The pilot bore is then enlarged by a second boring operation and all the drift tubes, properly supported and spaced on a mandrel, inserted into the cavities and brazed in position. The bore through the drift tube sections will thus be accurately aligned and serves as a reference for the alignment of the electron gun section on the R-F body section.

The composite body of the klystron, formed by the hermetically brazed blocks 22, 23 and 24, is supported between the pole pieces 8 and 26 by being brazed thereto. For this purpose the pole piece 26 is provided on its face adjacent the block 24 with a flat surface 49 extending radially away from a pad 50 formed adjacent the inner periphery of the pole piece 26 and within which the drift tube section 46 is brazed. At its outer periphery, surface 49 merges with a conical surface 51 diverging from the body block 24 and terminating at the outer periphery of the pole piece. The opposite face of the pole piece 26 is provided with a radially extending flat surface 52 terminating at its inner periphery in a cylindrical surface 53 which terminates at the inner periphery of the pole piece.

Minimum perturbation and/or distortion of a radio-frequency cavity is desirable to minimize heating due to R-F loses, as previously explained. However, it is desirable that each of the cavities be capable of being tuned within a least a limited range. Tuning means are therefore provided for each cavity by a diaphragm 58 shown best in FIGURES 4 and 7. Each of the diaphragms is preferably a flat copper sheet about .020" thick and having no convolution such as is usually the case with diaphragms of this type, the reason being that convolutions in a diaphragm cause undesired perturbations within the cavity. The peripheral edge portion of each diaphragm is hermeticaly brazed in a rabbet 59 formed in the surface 60 of each body block adjacent the cavity therein, as shown best in FIGURES 4 and 7.



Centrally disposed and brazed to he outer surface of each diaphragm is an internally threaded boss 61 projecting perpendicular to the axis of the drift tube sections, and cooperating with a tuning screw 62 to deform the diaphragm sufficiently to tune the cavity to the desired frequency. Initial tests indicate that .01" of diaphragm movement will shift the frequency about 5 mc. In the present embodiment the tuning screw 62 is associated with other elements to permit flexure of the diaphgarm in either direction irrespective of atmospheric pressure. To this end a jacket plate 63, having apertures 64 in registry with the bosses 61, is detachably secured over the face 60 of the body blocks. The side of the plate 63 adjacent the diaphargms is provided with a recessed surface 65 cooperating with peripheral edge portion 66 and the surface 60 of the body blocks, including the diaphragms, to form a passageway 67 for coolant fluid. In FIGURE 6, the transverse configuration of the passageway 67 is shown in dash lines.

The plate 63 is suitably secured to the body by means of cap screws (not shown) inserted through apertures 68 in the plate and threaded into tapped bores 69 in the body blocks. To form a fluid-tight seal about each of the apertures 64 in the plate, each of the tuning screws 62 is provided with a radially extending flange or seal plate 70, shown best in FIGURES 4 and 5, each of the flanges being provided with an O-ring gasket 71 adapted to form a fluid-tight seal with the top surface of the plate. It will thus be seen that a fluid coolant may be circulated through the passageway 67 under the plate in a manner to cool the diaphragms, the exposed edges of walls 29, 31, 34, 39, 40, 43 and 44 extending past the diaphragms, the remaining surfaces 60 of the blocks, and the tuning screws 62 and bosses 61.

It is desirable that once the desired operating frequency has been obtained that the tuning mechanism be protected in some manner, or partially covered to eliminate projecting tuning screws susceptible to unauthorized adjustment on impulse by careless personnel. For this purpose a cover plate 72 is provided, shown best in FIGURES 1 and 4, having apertures adapted to register with the tuning screw 62, and which is securely clamped on plate 63 by adequate cap screws 73. The thickness of the cover plate is such that the tuning screws do not project beyond its face so that the screws may not accidentally be turned. This may be aided where necessary by requiring a special tool to turn the screws. The underside of the plate is hollowed out to receive the flanges 70 and provide only sufficient clearance therefor to permit rotation thereof when the cap screws are tightened down, the underside of the plate 72 surrounding the hollowed-out portions bearing down tightly against the upper surface of the jacket plate 63. The tuning screws thus lie captured against axial movement between jacket plate 63 and cover plate 72. When each tuning screw is turned clockwise to deform the diaphragm outwardly, thrust is carried by jacket plate 63, while rotation of the tuning screw in the opposite direction will deform the diaphragm inwardly and thrust will be taken by the cover plate.

To provide adequate cooling for the radio-frequency structure and the magnetic pole pieces, each of the radio-frequency body blocks 22, 23, 24 is provided with passageways in a manner which will channel the fluid coolant so as to extract an optimum amount of heat from the body under the circumstances. To facilitate connection, the

cooling system for the tube body is connected in series with the cooling system for the magnetic circuit and preferably the tube body and magnetic circuit systems are connected in parallel with the collector cooling system, so that only a single supply of fluid coolant is required. This greatly reduces the complexity of setting the tube up for operation and thus reduces initial installation costs.

As shown in FIGURE 3, a fluid coolant, such as water, is admitted into the intermediate body block 23 through a suitable conduit 76. The inlet conduit communicates with a pair of longitudinally extending bores or passageways 77 formed in the block adjacent opposite outer side walls and at each end wall communicating with transversely extending passageways 78 and 79 formed, respectively, between the end walls 34–39 and 40–43 in a manner to completely surround an intermediate portion of the drift tube sections 36 and 41 with a sheet of high velocity turbulent fluid to thereby cool the drift tubes and adjacent body surfaces. Fluid entering through conduit 76 flows in both directions through the associated bore 77 and into the passageways 78 and 79 at opposite ends of block 23. Passageways 78 and 79 communicate with corresponding longitudinally extending bores or passageways 81 formed in body block 24. These latter passageways terminate in a passageway 82 formed about the drift tube section 46 and defined by the end wall 44, the inner end of the pad 58 and surface 49 on pole piece 26. High velocity fluid coolant circulating turbulently through the passageway 82 extracts heat from the drift tube section 46, from pole piece 26, and from the end of body block 24. It should be noted that the passageways 78, 79 and 82 are arranged in parallel connection with each other through longitudinally extending passageways 77 and 81 in order to reduce the pressure drop in the system. It should also be noted that the cross-sectional area of passageways 77 and 81 on opposite sides of the associated blocks vary so as to ensure the flow of an equal volume of fluid coolant through pasageways 78, 79 and 82, the ends of the longitudinally extending pasageways 77 and 81 being chamfered as shown to reduce the pressure drop in the system by smoothing the transition from longitudinal to transverse flow.

Fluid from these passages combines and passes through an aperture 83, shown in FIGURE 7, and flows into the passageway 67 formed between the top surface 60 of the body and the undersurface 65 of the jacket plate 63. From the aperture 83 and its entry into the passageway 67, the fluid flows turbulently and at high velocity about and over the tuning mechanism, extracting heat therefrom, and then flows into a pair of parallel bores or passageways 84 at opposite corners of the body block 22. It will thus be noted that the passageway 67 forms a series connection between the parallel passageways 78, 79 and 82 as one group and the parallel passageways 84 as another group.

The passageways 84 extend through the body block 22 at right angles to the drift tube sections and adjacent the side walls of the block. They communicate with longitudinally extending passageways 85 adjacent opposite sides of the body section 22, and also adjacent the top surface 60 thereof within which the deformable diaphragms are mounted. The passageways 85 are best shown in FIGURES 3 and 9, and as there shown, these passageways communicate with passageways 86 parallel to each other and to passageways 84, but perpendicular to passageways 85. From the vertically extending parallel passageways 86, fluid coolant passes into a transversely extending passageway 87 extending under the resonant cavity 28 wherein it recombines and from which it passes in series into the outlet conduit 88. From the foregoing it will be apparent that each of the body blocks 22, 23 and 24 has been fabricated in a manner so that when the blocks are put together into the composite assembly illustrated in FIGURE 3, the coolant passageways are intercommunicated in a manner to permit a fluid coolant to circulate therethrough at high velocity, extracting heat from every portion of the body and drift tube structure. Additionally, it will be noted that the cooperative relationship between the pole pieces 8 and 26, and the intervening composite copper body, is such as to permit extraction of heat from the pole pieces and into the circulating fluid. This is particularly true with respect to the pole piece 8, in which the broad thermal contact between the copper plug 19 and the pole piece 8 along the conical surface 18 draws heat from the pole piece 8 into the body structure from which it is transferred to the fluid coolant. Such efficient cooling of the structure enables a high power output of at least 20 kilowatts CW.

As shown best in FIGURE 1, the intercommunication of the cooling systems for the magnetic circuit and the radio-frequency interaction section are connected in series and enable a single source of fluid coolant to circulate through both systems. Because efficient operation of a tube operating at the power level which this tube operates requires a high gauss magnetic field, in the range of about 3000–5000 gauss, it is desirable that the magnetic coils 91 and 92 be cooled, and for this purpose the coils, which are of the conventional foil-wrapped type, have been modified by the addition of heavy metallic end plates 93 in thermal contact with the edges of the foil. Thus, as current passes through the coil and generates heat, the heat is conducted by the foil to the outer edges thereof where it is transferred to the plates 93. To extract heat from the plates 93, each is provided with a coolant conduit 94 in thermal contact therewith as by brazing, and connected to an input conduit 96.

Thus, as shown in FIGURE 1, water enters the conduit 96 and courses through the conduit 94 surrounding the lower magnetic coil, and exits through the conduit 97 which is connected to the input conduit 76 leading into the radio-frequency body structure. The output conduit 88 from the radio-frequency body is connected to an input conduit 98 leading into the coolant conduit 94 associated with the upper magnetic coil 92. After coursing through this conduit, the fluid coolant exits through output conduit 99. With this construction it will be apparent that the temperature concomitant to the heat generated in the magnetic coils may easily be maintained within permissible limits.

In a tube of this character, it is important that secondary electrons liberated within the collector be trapped therewithin and not be permitted to strike the tube body. The reason for this is that the percentage beam transmission may be calculated from a measured value of body current. When secondary electrons from whatever source strike the tube body, the measured value of body current is not representative of beam interception by the body. For the purpose of minimizing bombardment of the tube body by secondary electrons, the collector 101, having fluid inlet and outlet couplings 101*a* and 101*b*, respectively, is provided with an interior surface 102 to collect the spent electron beam, and is additionally provided with an apertured baffle plate 103 in the nature of a truncated cone having a conical surface lying parallel to but spaced from the surface 54 of the pole piece 26. As the electron beam emerges from the radio-frequency structure and passes through the apertured apex end of the baffle 103, the electrons spread and strike the inner surface 102 of the collector. If such primary electrons have a velocity sufficient to liberate secondary electrons, such secondary electrons might return in the direction of the radio-frequency structure, and, in the absence of baffle 103, would strike the pole piece 26. Since the pole piece 26 is in direct electrical contact with the body, the body current would to some extent be determined by the number of secondary electrons striking the pole piece, and would therefore render substantially useless as an indication of beam interception a measured value of body current. The baffle 103 intercepts such secondary electrons and there-

fore shields the radio-frequency structure from their effect.

Further isolation of the R-F body from the collector is effected by the interposition between pole piece **26** and the collector body of electrically insulating means comprising a plurality of axially aligned dielectric wafers **104** surrounding a cylindrical extension **106** between the collector body and the conical baffle plate **103**. The dielectric wafers are sandwiched as shown and are hermetically brazed on opposite ends to metallic flanges **107** and **108**, which cooperate to hermetically unite the collector body to the pole piece **26**. The flange **108** preferably has its outer peripheral portion captured in a slot **109** formed in the pole piece face **52**, while its inner periphery is sandwiched between two dielectric wafers and brazed to each. Additionally, flange **108** is provided with a hump or convolution **110** which permits some degree of flexibility in the union between the collector and the body portion of the tube to accommodate differences in expansion and contraction between the copper collector and iron pole piece **26**. As is well known, copper has a substantially linear thermal expansion and contraction characteristic, whereas iron has a thermal expansion and contraction characteristic which is nonlinear and divergent from that of copper. It is therefore necessary to accommodate these different characteristics by a flexible union as provided by flange **108**. Flanges **107**, on the other hand, are rigidly brazed to the collector section to provide outer registering edge **111** which may be heliarc-welded to form the final hermetic seal between the collector section and the radio-frequency body section of the tube.

After assembly in the manner described is completed, the tube is evacuated through a suitable tubulation **113** communicating with the interior of the input waveguide **114** as shown in FIGURE 4. An output waveguide **115** is provided communicating with the output cavity **42**. The tube is then fitted into its magnetic circuit shown in FIGURE 1. The magnetic circuit preferably comprises a heavy base plate **116** formed from heavy cold-rolled steel bar stock, and provided with a central aperture within which is secured a longitudinally extending cylindrical pole piece **117**. The inner end of the cylindrical pole piece is appropriately rabbeted to provide a seat **118** adapted to receive the outer peripheral portion of the pole piece **26**. The diameter of the pole piece **117** is such as to permit the ready passage of the collector therethrough. At its lower end the cylindrical pole piece **117** is preferably press-fitted into the seat **119** provided therefor by a rabbet formed in the inner periphery of the central aperture in plate **116**.

Extending vertically from base plate **116**, are laterally spaced and longitudinally extending magnetizable bar members **121**, secured to the base plate **116** by appropriate cap screws **122**. The opposite ends of the magnetic bar members **121** are joined by transversely extending magnetic bar **123**. The transverse bar is secured to the upper ends of the vertically extending bars **121** by cap screws **124** as shown in FIGURE 1.

The bar **123** is provided with a central aperture similar to the aperture formed in base plate **116**, and accommodates a cylindrical pole piece **126** in sliding engagement therewith, the inner end of the pole piece being rabbeted in the same manner as the pole piece **117** to provide a seat **127** for the pole piece **8**. The pole pieces **126** and **8** therefore cooperate to provide controlled magnetic shielding for the electron gun which lies nestled within the cylindrical pole piece **126**, some magnetic flux being permitted to "leak" through the aperture in the pole piece and given direction to match the trajectory of the electrons by the configuration of conical surface **18**. Surrounding the pole piece **126** is the magnetic coil **92**, as shown in FIGURE 1, having its upper end plate **93** appropriately secured as by bolts (not shown) to the underside of the bar **123** to suspend the coil in position.

To enable hoisting the bar **123** and attached coil into and out of engagement with side bars **121** to enable positioning of the tube within the cylindrical pole piece **117**, a pair of "eye" bolts **127** are secured in bar **123**. By means of a suitable hoist and a cable extending through the "eye" bolts, this entire subassembly may be hoisted into or out of position when desired. After placement of the cylindrical pole piece **126** about the gun section of the tube, the bar **123** and attached coil **92** may be positioned thereabout and secured by cap screws **124**. The apparatus as a whole is secured to a suitable support by suitable fastening means passing through apertures **128** in cross bar **116** adjacent its outer ends as shown in FIGURE 1.

I claim:

**1.** A beam tube comprising a vacuumized envelope including an electron gun section, a radio-frequency interaction section and a collector section axially aligned and hermetically united, said radio-frequency interaction section comprising a plurality of initially separate composite metallic blocks being hermetically united onto the other to serially align said cavities, and a drift tube section extending into each block and defining an electron drift space communicating with the cavity therein, adjacent ends of two such drift tubes defining an interaction gap within each cavity, said metallic blocks of said radio-frequency interaction section defining a plurality of intercommunicating fluid passageways for the passage of fluid coolant therethrough including a first set of parallel passageways extending transversely across the radio-frequency interaction section to channel fluid coolant about a corresponding number of said drift tube sections, at least a second set of parallel passageways extending transversely through said radio-frequency interaction section parallel to said first set of transversely extending passageways, and a third passageway having a portion extending transversely and a portion extending longitudinally of the radio-frequency interaction section and serially connecting the first and second parallel sets of passageways.

**2.** The combination according to claim **1**, in which the portion of said third passageway extending longitudinally of the radio-frequency interaction section is outside said blocks to channel fluid coolant over an exterior surface portion thereof.

**3.** The combination according to claim **1**, in which each said cavity is closed on one side by a deformable diaphragm to effect limited tuning of each cavity, and said diaphragms constitute a portion of the walls of said passageway outside said blocks.

**4.** The combination according to claim **1**, in which said first set of parallel passageways are associated with two of said blocks next adjacent the collector, the second set of said passageways is associated with the block next adjacent the electron gun, and said third set of passageways is associated with all said blocks forming the radio-frequency interaction section.

**5.** In a beam tube apparatus including a beam tube having a radio-frequency interaction section comprising a plurality of hermetically united metallic blocks each hollowed to provide at least one resonant cavity therewithin, and a drift tube section extending between adjacent blocks, a magnetic circuit having at least one magnetic coil and a magnetic frame, said metallic blocks define a plurality of intercommunicating sets of passageways in said radio-frequency interaction section for the passageway therethrough of a fluid coolant, at least one pasageway in said magnetic circuit in heat transfer relation to said magnetic soil, and conduit means serially connecting one of said sets of passageways in the radio-frequency interaction section with the passageway in said magnetic circuit.

**6.** The combination according to claim **5**, in which said collector has inlet and outlet couplings for a fluid coolant, the inlet coupling of said collector adapted to be connected to a source of fluid coolant in parallel connection with said serially connected passageways in the radio-frequency interaction section and magnetic circuit.

**7.** In combination with an electron beam tube having

an evacuated envelope and axially spaced annular ferromagnetic pole pieces forming part of the evacuated envelope, a magnetic circuit comprising a pair of axially spaced and parallel elongated ferromagnetic frame members having centrally disposed apertures therein and mutually extending axially aligned tubular ferromagnetic pole piece extensions perpendicular to said frame members and axially spaced to have facing ends, the facing ends of said tubular ferromagnetic pole pieces engaging said axially spaced annular ferromagnetic pole pieces forming part of the evacuated envelope, one of said tubular ferromagnetic pole piece extensions being slidably disposed in the associated ferromagnetic frame member, parallel ferromagnetic side members connecting corresponding ends of said axially spaced ferromagnetic frame members to complete a magnetic circuit having a gap defined by said pole pieces forming part of the evacuated envelope, and an energizable magnetic coil within the frame surrounding each of said tubular ferromagnetic pole piece extensions to energize said magnetic circuit.

8. In a beam tube, a radio-frequency interaction section comprising a plurality of initially separate composite metallic blocks hollowed to provide at least one resonant cavity within each block, said blocks being hermetically united one to the other to serially align said cavities, drift tube sections communicating with each cavity and arranged to provide an interaction gap therewith, a substantially flat diaphragm hermetically closing one side of the cavity and deformable to tune the cavity, a jacket plate mounted to cover said diaphragm, said jacket plate cooperating with adjacent surfaces of said blocks and diaphragm to define a passageway for fluid coolant over the outer surface of the blocks adjacent the diaphragm, a tuning member extending through said jacket plate to connect to each diaphragm and adjustable to effect selected deformation of the associated diaphragm, and fluid type seal means interposed between said tuning member and said jacket plate, said metallic blocks defining a plurality of intercommunicating fluid passageways for the passage of fluid coolant therethrough including a plurality of parallel passageways extending transversely across the radio-frequency interaction section to channel fluid coolant about a corresponding number of said drift tube sections and at least one passageway extending longitudinally through said radio-frequency interaction section parallel to said drift tube sections, said longitudinally extending passageway and said passageway defined by said jacket plate intercommunicating said transversely extending pasageway.

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# UNITED STATES PATENT OFFICE

# CERTIFICATE OF CORRECTION

Patent No. 3,344,306 September 26, 1967

Martin E. Levin

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 10, line 63, "passageway" should read -- passage --; line 66, "soil" should read -- coil --. Column 12, line 12, "passageway" should read -- passageways --.

Signed and sealed this 23rd day of December 1969.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents