Jan. 21, 1947. A. E. HARRISON ET AL 2,414,785

HIGH FREQUENCY TUBE STRUCTURE

Filed Jan. 29, 1942 7 Sheets-Sheet 1

FIG. 1

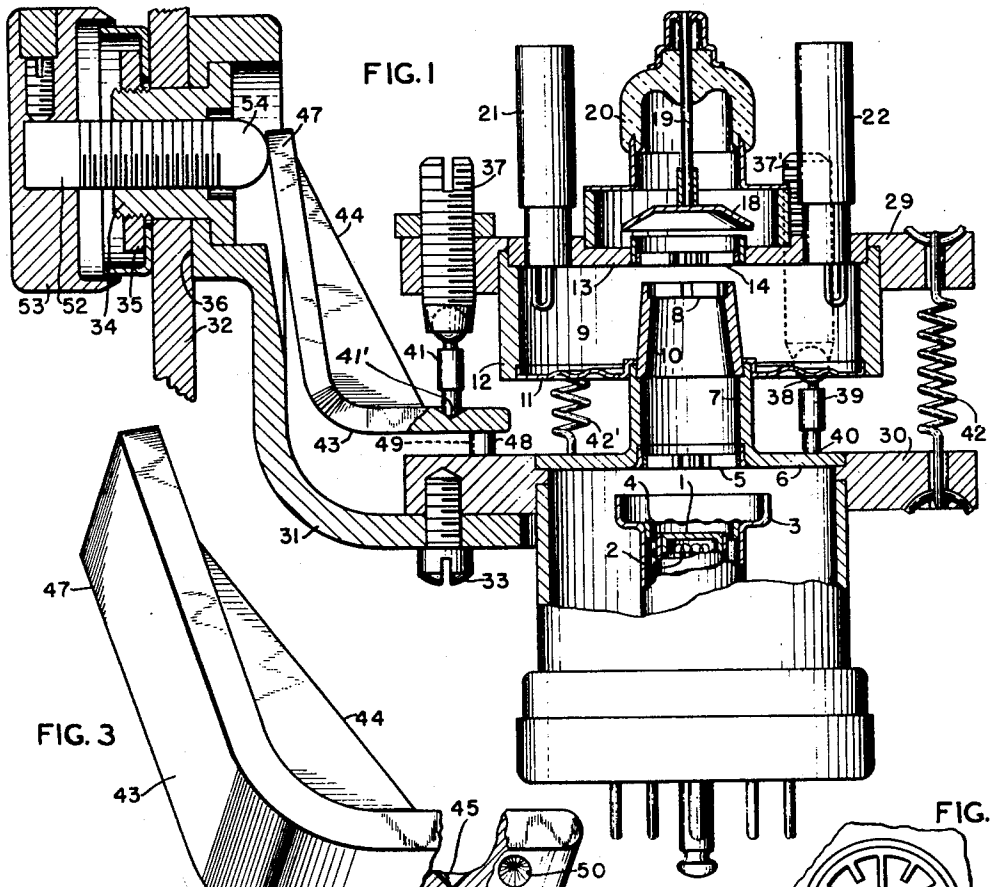


FIG. 3

FIG. 5

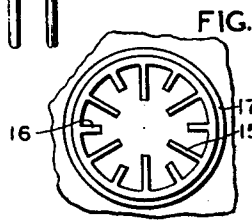


FIG. 4

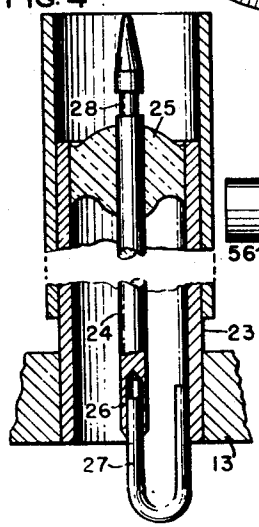


FIG. 6

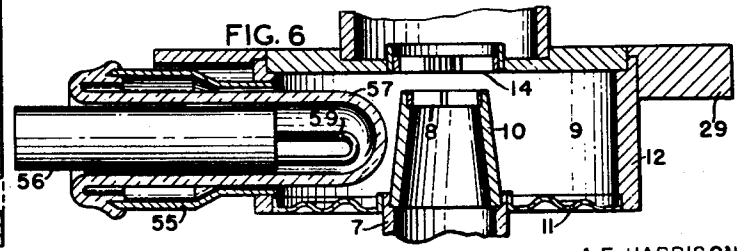
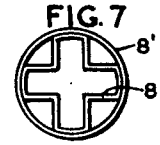


FIG. 7



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Jan. 21, 1947. A. E. HARRISON ET AL 2,414,785

HIGH FREQUENCY TUBE STRUCTURE

Filed Jan. 29, 1942 7 Sheets-Sheet 2

FIG. 2

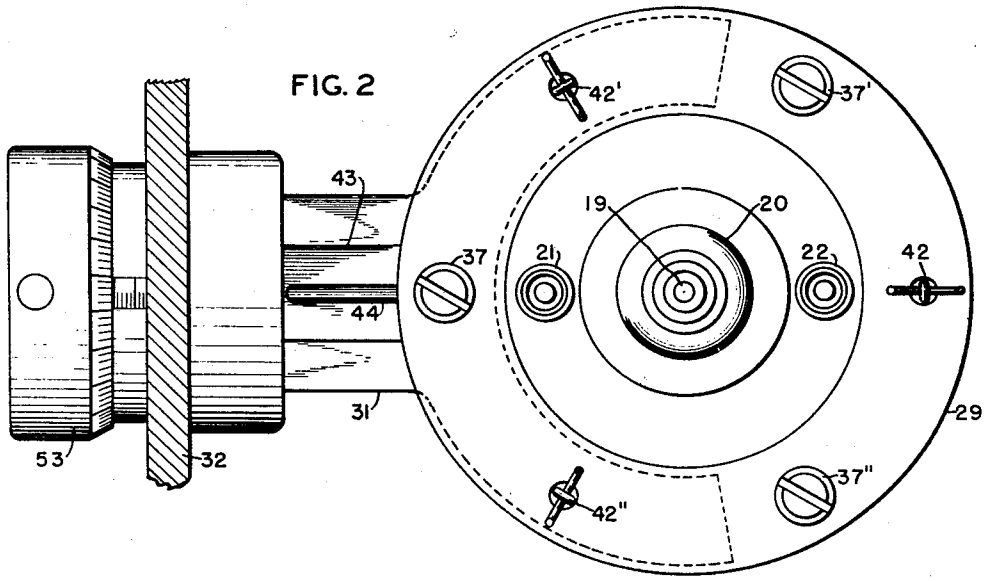
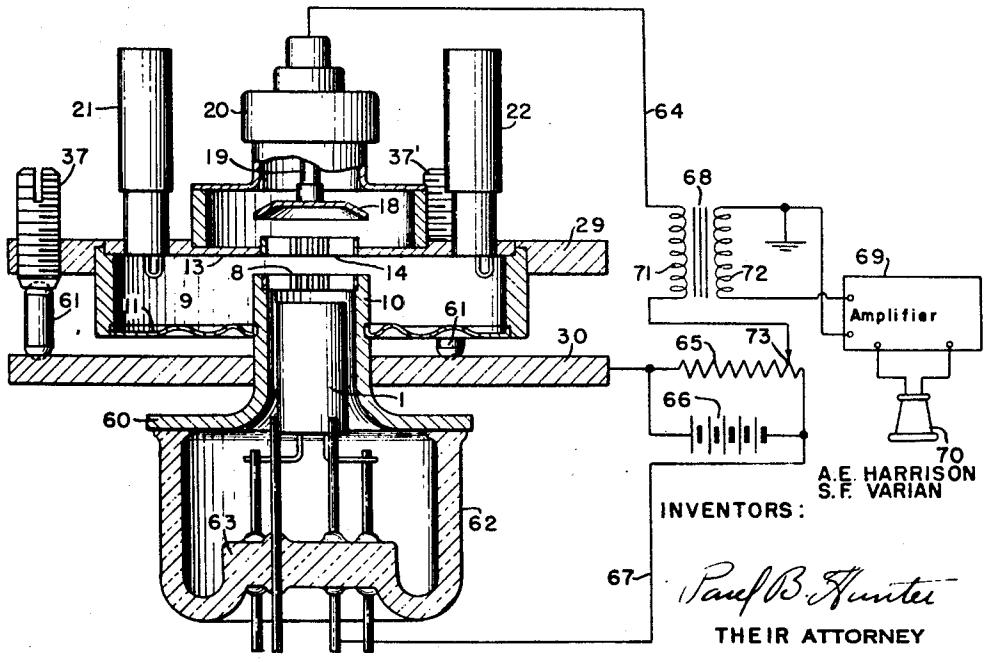


FIG. 8



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HIGH FREQUENCY TUBE STRUCTURE

Filed Jan. 29, 1942 7 Sheets-Sheet 3

FIG. 9

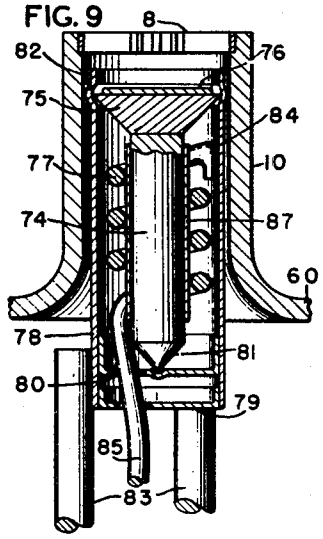


FIG. 10

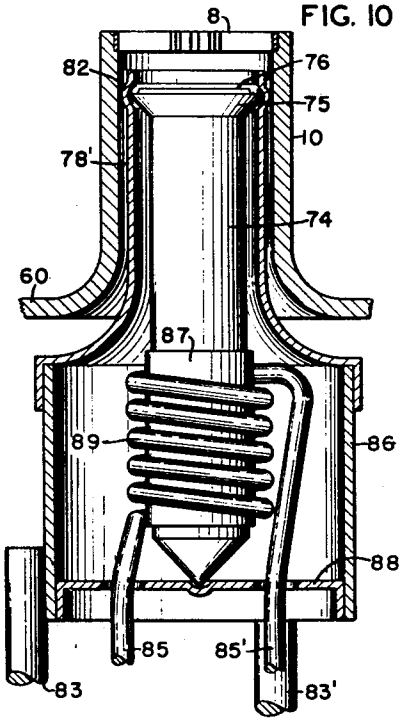


FIG. 11

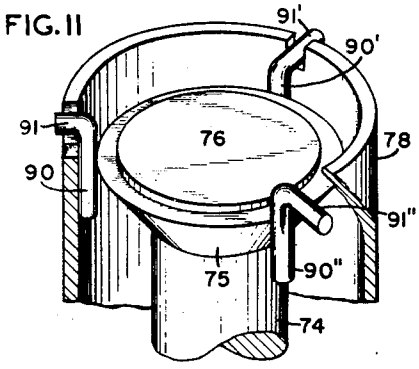


FIG. 14

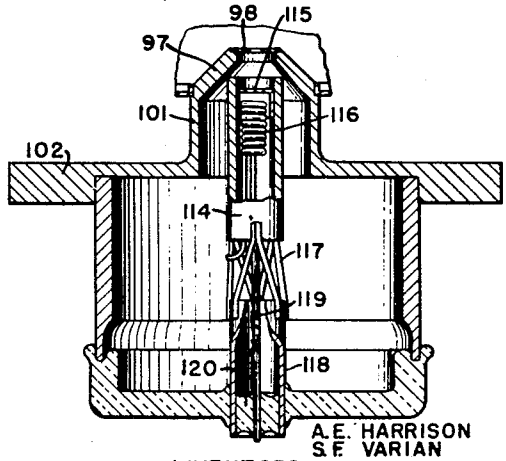
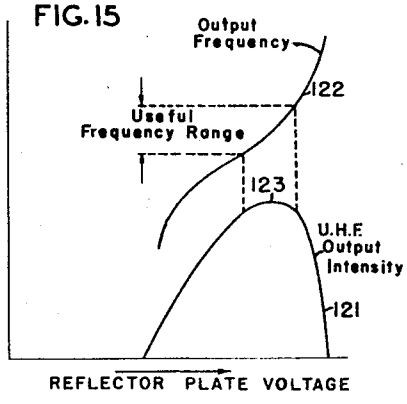


FIG. 15



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Jan. 21, 1947. A. E. HARRISON ET AL 2,414,785

HIGH FREQUENCY TUBE STRUCTURE

Filed Jan. 29, 1942 7 Sheets-Sheet 4

FIG. 13

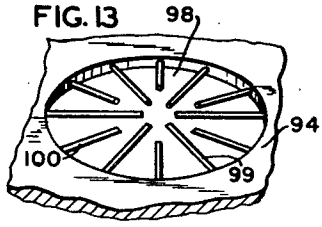


FIG. 12

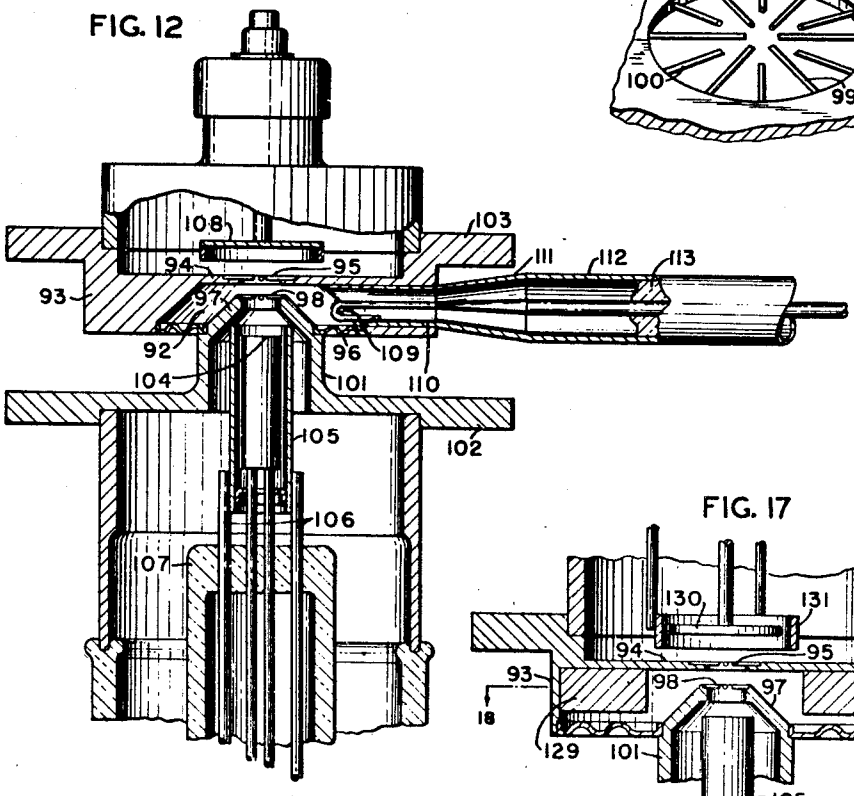


FIG. 17

FIG. 16

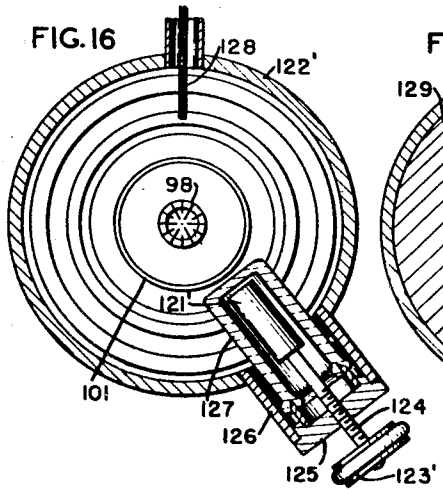
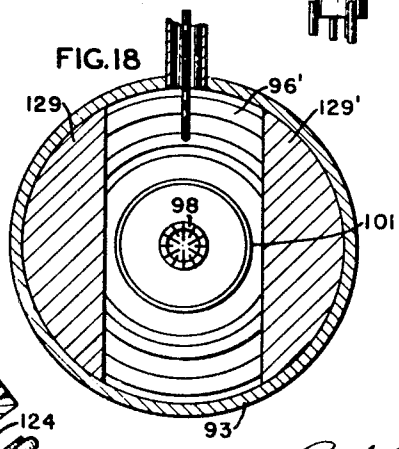


FIG. 18



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Jan. 21, 1947. A. E. HARRISON ET AL 2,414,785

HIGH FREQUENCY TUBE STRUCTURE

Filed Jan. 29, 1942 7 Sheets-Sheet 5

FIG. 19

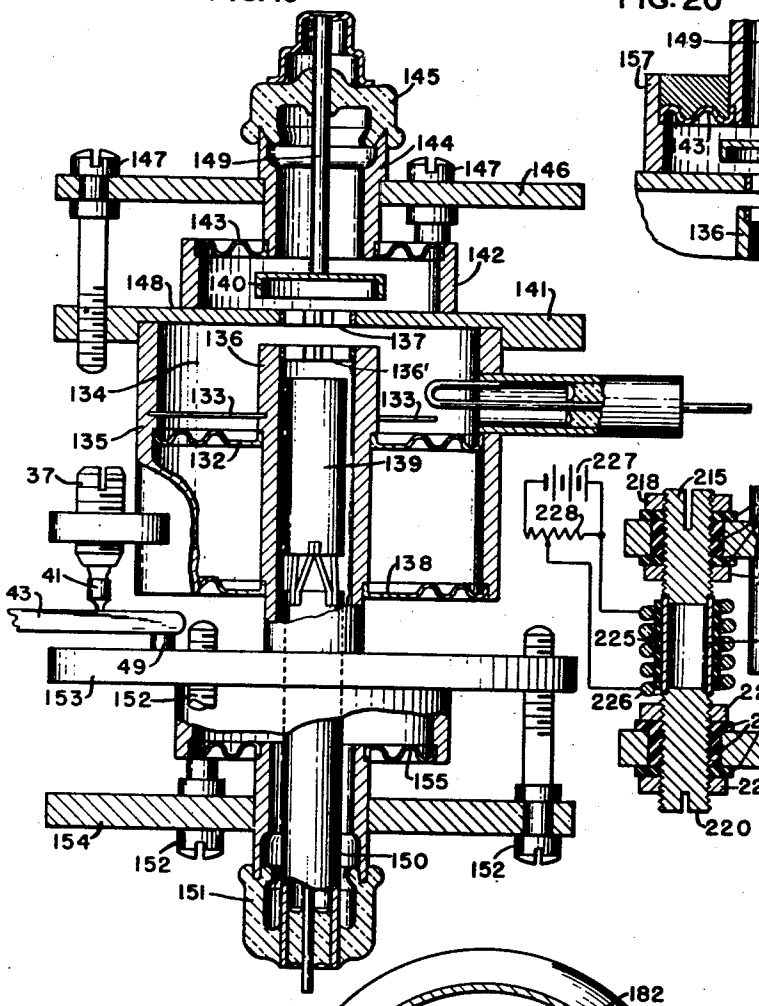


FIG. 20

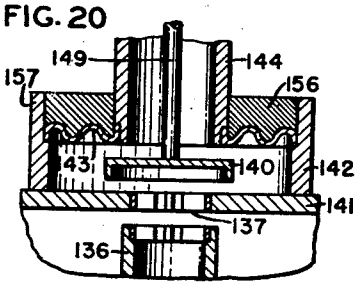
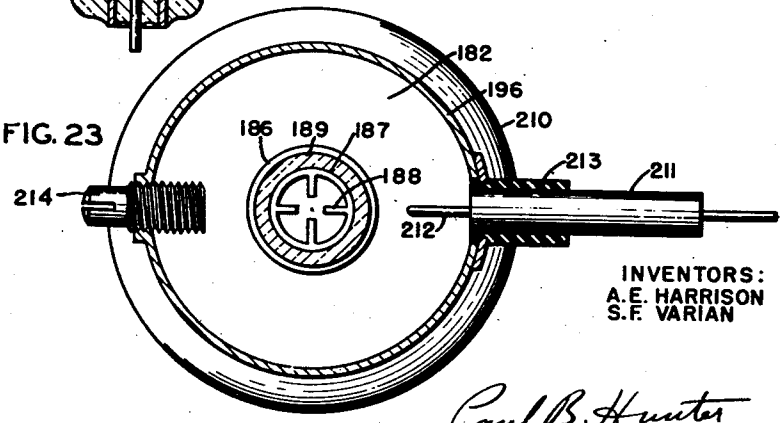


FIG. 24

FIG. 23



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Jan. 21, 1947. A. E. HARRISON ET AL 2,414,785

HIGH FREQUENCY TUBE STRUCTURE

Filed Jan. 29, 1942 7 Sheets-Sheet 6

FIG. 21

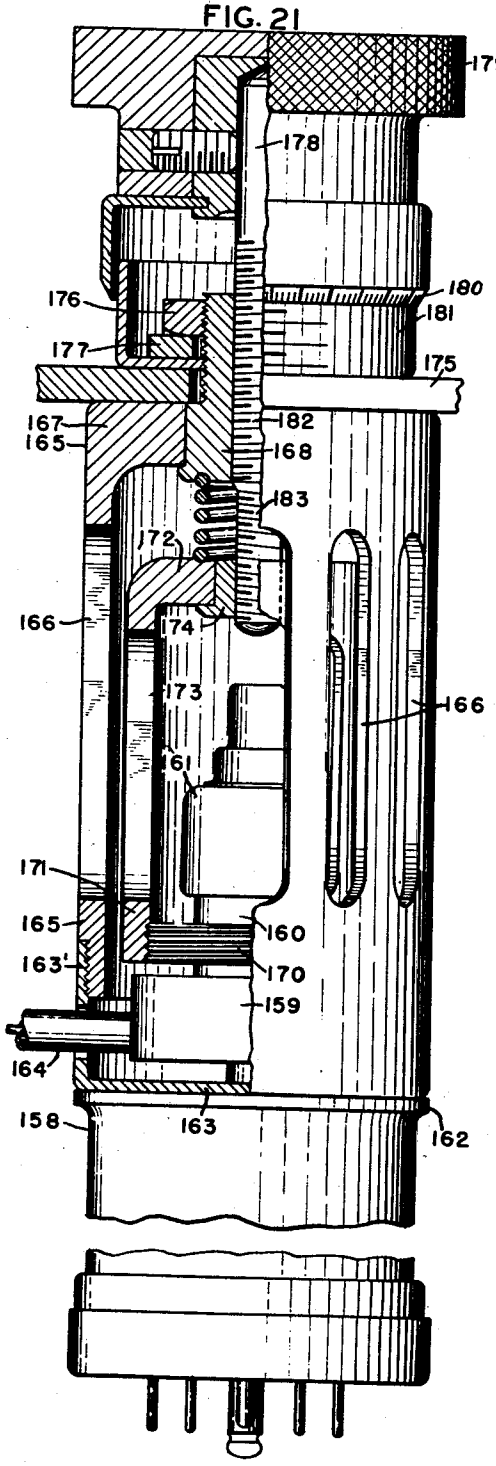
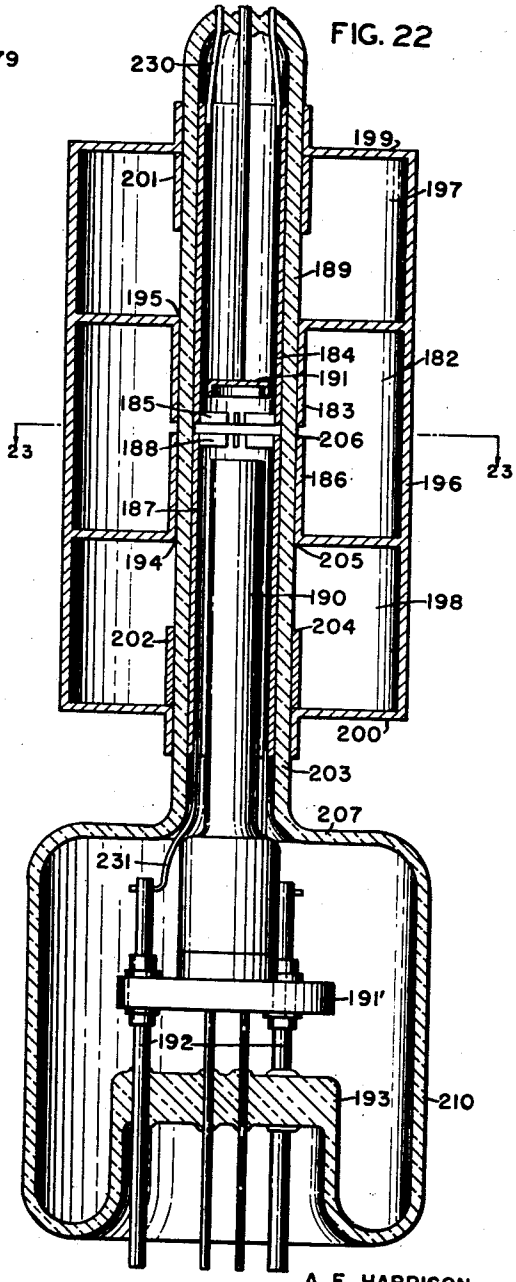


FIG. 22



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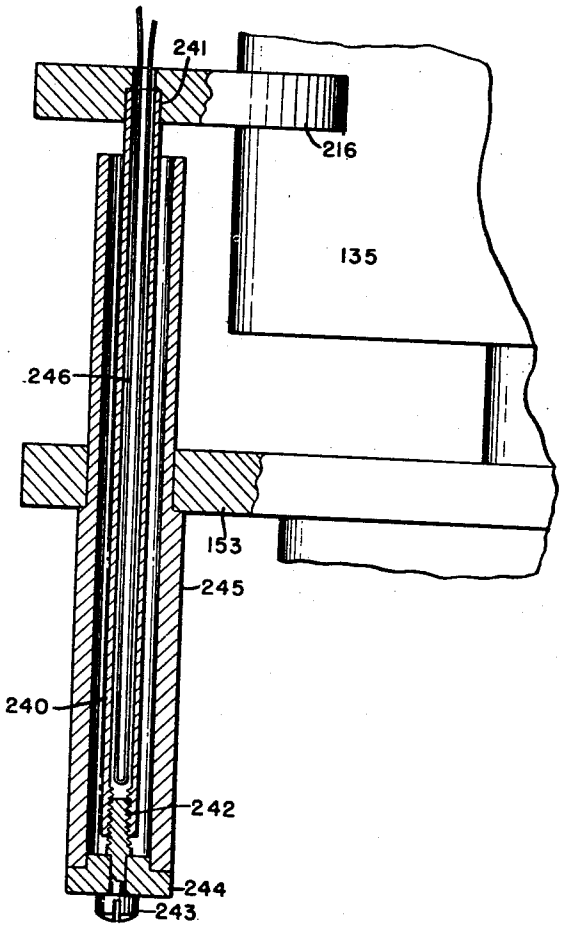
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Jan. 21, 1947. A. E. HARRISON ET AL 2,414,785

HIGH FREQUENCY TUBE STRUCTURE

Filed Jan. 29, 1942 7 Sheets-Sheet 7

FIG. 25



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Patented Jan. 21, 1947

2,414,785

UNITED STATES PATENT OFFICE

2,414,785

HIGH-FREQUENCY TUBE STRUCTURE

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Application January 29, 1942, Serial No. 428,682

25 Claims. (Cl. 250—27.5)

1

This invention relates, generally, to ultra high frequency vacuum tube structure; and, more specifically to ultra high frequency devices of the electron beam type such as disclosed in Patents No. 2,245,627, entitled "Stabilization of frequency," issued June 17, 1941, in the name of Russell H. Varian, No. 2,250,511, entitled "Oscillator stabilization system," issued July 29, 1941, in the names of Russell H. Varian and William W. Hansen and No. 2,259,690, entitled "High-frequency radio apparatus," issued October 21, 1941, in the names of John R. Woodyard, William W. Hansen and Russell H. Varian. In the aforementioned disclosures, there is shown an ultra high frequency device consisting of an indirectly heated cathode which projects an electron beam through grids which form portions of the opposite walls of a hollow cavity conducting resonator. After the electron beam leaves the exit grid of the resonator, it is reflected back through the resonator by means of a reflector electrode operating at or very near to the potential of the cathode. If a high frequency alternating electric field exists between the resonator grids due to the presence of a corresponding high frequency alternating electromagnetic field in the resonator, the electron beam suffers recurrent velocity changes by the action of said alternating electric field during its initial passage through the resonator. As the electron beam passes through the exit grid of the resonator and onward, the effect is to commence to produce recurrent grouping of the electron beam. The spacing between the resonator exit grid and the reflector electrode, and the voltage on said electrode, are so arranged that the electrons are reflected back into the resonator at a time when the recurrent velocity changes have resulted in recurrent grouping of the electron beam and at a time such that these electron groups return energy to the alternating electric field appearing between the resonator grids, thus maintaining the oscillating electromagnetic field inside of the resonator. Direct current energy is thus introduced into the device by means of the electron beam, and may be removed as ultra high frequency energy from the hollow resonator by means of coupling loops and associated concentric line elements, as more fully described in the aforementioned patents.

One object of the present invention is the provision of improved tuning means for high frequency tube structures of the type employing a single resonator such as disclosed in the above-mentioned patents, suitable for operating at wavelengths on the order of ten centimeters or less.

2

Another object of the present invention is to provide improved cavity resonator electron-discharge tube structure of the reflex type suitable for operation at wavelengths on the order of 10 centimeters or less.

A further object of the present invention is to provide improved combined mounting and tuning means for high frequency tube structures containing cavity resonators.

Other objects and advantages of this invention will become apparent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 is an elevational and partially cross-sectional view of a preferred form of the vacuum tube and tuner mechanism of the present invention.

Fig. 2 is a plan view of Fig. 1.

Fig. 3 is a perspective view of a detail of Fig. 1.

Fig. 4 is a cross-sectional view of an element of Fig. 1.

Fig. 5 is a fragmentary plan view of a detail of Fig. 1.

Fig. 6 is a cross-sectional elevation view of an alternate form of a portion of Fig. 1.

Fig. 7 is an elevational view of a grid structure.

Fig. 8 is a cross-sectional elevational view, with parts omitted, of an alternate form of the structure shown in Fig. 1, together with a schematic wiring diagram.

Fig. 9 is a fragmentary cross-sectional view of a detail of Fig. 8.

Fig. 10 is a similar view of an alternate form of the structure of Fig. 9.

Fig. 11 is a perspective view of a modification of the structure shown in Fig. 9.

Fig. 12 is a partially cross-sectional elevational view of an alternate of the structures shown in Figs. 1 and 8.

Fig. 13 is a fragmentary perspective view of a detail of Fig. 12.

Fig. 14 is a fragmentary cross-sectional elevational view of an alternate form of the cathode structure shown in Fig. 12.

Fig. 15 is an explanatory graph.

Fig. 16 is a cross-sectional plan view of a resonator similar to that of Fig. 8.

Fig. 17 is a fragmentary cross-sectional elevation view of an alternate form of a portion of Fig. 12.

Fig. 18 is a cross-sectional plan view taken along the line 18—18 of Fig. 17.

Fig. 19 is a partial cross-sectional elevational view of an alternate form of Figs. 1, 8, and 12.

Fig. 20 is a cross-sectional elevation view of a modification of a detail of Fig. 19.

Fig. 21 is a partial cross-sectional elevation view of an alternate form of the structure shown in Figs. 1, 8, 12 and 19.

Fig. 22 is an elevation view in cross-section of a modified form of the device shown in Fig. 1.

Fig. 23 is a cross-sectional plan view taken along the line 23—23 of Fig. 22.

Fig. 24 is a fragmentary partial cross-sectional elevation view of an alternate form of a portion of the structure of Fig. 19.

Fig. 25 is a fragmentary cross-sectional elevation view of an alternate form of the structure of Fig. 24.

Similar characters of reference are used in all of the above figures to indicate corresponding parts.

In Fig. 1 there is shown a single resonator electron beam velocity-modulating tube structure of the type disclosed in the aforementioned patents, together with a novel type of frequency-adjusting mechanism. The cathode structure consists of emitter surface 1, which may be of the oxide-coated type, heated by resistance heater 2, emitter 1 being coaxial with and surrounded by focusing shield 3 which is illustrated as containing a woven mesh grid 4, that may act as a control or modulator grid, as desired. Electrons from emitter 1 may be projected in a beam of round cross-section through accelerating and field smoothing grid 5 by means of any suitable unidirectional voltage applied between cathode 1 and a plate 6. Plate 6 is provided with a cylindrical neck portion 7 in which grid 5 is mounted and which serves to provide a field-free space in which the electron beam travels toward and through entrance grid 8 of a hollow conducting resonator 9. Resonator 9, as shown, as a reentrant portion 10, a flexible end wall 11, an outer cylindrical wall 12, and rigid flat end wall 13 opposite to wall 11. End wall 13 of resonator 9 is apertured and carries a grid structure 14 concentric with and close to grid 8. Grids 5 and 14 may, as shown in Fig. 5, consist of an annular member provided with alternate long and short radial conducting bars 15 and 16 and inserted in rings 17, which in turn are inserted in plate 6 and end wall 13. Grid 8 may be made of strip material put preferably into cruciform shape and secured in a ring 8' as illustrated in Fig. 7. The elements of grids 5, 8, and 14 may be made of zirconium or other metals which emit relatively few secondary electrons. Spaced concentric to grid 14 and close behind it is reflector electrode 18 which may be dish-shaped as shown. Reflector 18 is supported by conductor 19 which passes through glass end bell 20, which is in turn supported by end wall 13 of resonator 9 in the conventional manner.

In operation, the electron beam emitted from cathode 1 is projected through accelerating and smoothing grid 5 and through entrance grid 8 into resonator 9. In this resonator the beam suffers recurrent velocity changes or is velocity-modulated by means of an oscillating electric field existing between grids 8 and 14. The beam travels out through exit grid 14 and is reflected back through grid 14 by a voltage applied to reflector 18 very near that of the cathode 1 voltage, the reentry of the beam into resonator 9 taking place after recurrent bunching or density modulation of the beam has taken place, said grouped electron beam then giving up energy to the electric field between grids 14 and 8, thus maintaining oscillations in resonator 9.

Resonator 9 may be provided with coaxial line terminal posts or elements 21 and 22, emerging from resonator end wall 13. Coaxial line posts 21 and 22 may be similar in construction to that shown in Fig. 4, which is the sole invention of John R. Woodyard and is described and claimed in his copending application entitled "High-frequency terminal" filed on December 14, 1946. In this figure, a tube 23 which may be of "Kovar" or other metal readily sealable to glass, forms the outer conductor of the concentric line post and is inserted into an aperture in wall 13 of resonator 9. The inner rod 24, concentric to tube 23, serves as the inner conductor, may be of tungsten, and is positioned by glass seal 25. Inner end 26 of rod 24 supports one end of coupling loop 27, the other end being welded to the inner end of tube 23.

The outer end of inner conductor 24 is conical to facilitate fitting of the inner conductor of the concentric line to be thereto attached. Slightly above the outer surface of glass seal 25, rod 24 has a constricted section 28. It is found that without the small diameter section 28, if the end of rod 24 is accidentally hit, glass seal 25 would break near rod 24; but that if the constricted section 28 is provided, section 28 merely bends if accidentally hit, and the seal 25 is not broken.

Concentric line terminal posts 21, 22 may be placed so that they project radially from cylindrical wall 12, as shown in the aforementioned Patent No. 2,245,627. A structure such as shown in Fig. 6 may also be used, in which a coaxial line terminal post 56 of conventional type or similar to that shown in Fig. 4 is adjustably positioned in a reentrant tube 57 of low loss glass, tube 57 being sealed to a concentric metal tube 55 inserted in wall 12 to provide continuity of the vacuum envelope. It is evident to one skilled in the art that rotation of the post 56 and hence of the coupling loop 59 out of the plane shown in Fig. 6 decreases the coupling between resonator 9 and coaxial line post 56, and this is also true if post 56 is moved outwardly.

End plate 6 and end wall 13 in Fig. 1 are provided with flange extensions 30 and 29, respectively, which flange extensions are perpendicular to the axis of the tube. The entire structure may be supported as from a panel 32 by means of a forked bracket 31 which is clamped to flange 30 by screws 33, as is seen in Fig. 1. Bracket 31 has an inner threaded cylindrical portion 34 which is adapted to fit through a round hole in panel 32. The external diameter of cylindrical portion 34 is threaded to receive nut 35 which clamps bracket 31 to panel 32, by forcing panel 32 against shoulder 36 of bracket 31.

Flange 29 is shown provided with three screws 37, 37', 37'' which may be spaced 120° apart near the periphery of said flange, their slotted ends facing away from flange 30. Screws 37' and 37'' are provided on their inner ends with socket joints 38 for receiving the spherical ends of cylindrical struts 39, which struts have hemispherical ends 40 bearing in sockets in flange 30. Screw 37 is likewise provided on its inner end with a socket for linking said screw with strut 41 that is similar to struts 39. Strut 41 has a hemispherical end 41' thrusting against a conical seat 45 provided in a lever 43. Lever 43, as seen in Fig. 3, consists of transverse portion 46 and a portion 47 extending at approximately right angles there-

to, the lever 43 being braced by a web portion 44. A pivotal support for the lever is provided by two studs 48 and 49 supported in flange member 30. The upper end of stud 48 fits into conical hole 50 in the bottom surface of lever portion 46, while the upper end of stud 49 fits into a milled slot 51 of V-shaped cross-section, said slot extending at right angles to the length of lever 43, and in line with hole 50.

Struts 39 and strut 41 are forced to bear with a proper force against flange 30 by three springs 42, 42', 42'' which are under tension between flanges 29 and 30, which may be spaced 120° apart near the peripheries of said flanges, and which may be 60° from the screws 37, 37', 37''. It is thus seen that a kinematic lever arrangement has been provided which is not overconstrained and has as its degree of freedom the ability to be rotated about the pivotal supports 48, 49, in the plane of the drawings of Fig. 1, thus imparting motion to stud 41 and flange 29 and flexing wall 11, for varying the distance between grids 8 and 14, thereby changing the natural frequency of the hollow resonator 9.

Actual movement of the lever portion 47 is produced by rotation of a screw 52 by a knob 53. Screw 52 has a hemispherical face 54 which bears against the outer face of lever portion 47. Relative placement of pivots 48, 49 and stud 41 and the pitch of screw 52 determine the fineness of the resultant frequency adjustment. Rough adjustment may be provided by the rotation of screws 37, 37', 37''.

Fig. 8 discloses a modification of the tube structure shown in Fig. 1 having a low frequency shift with thermal changes and other advantages to be further explained. This structure is the sole invention of Sigurd F. Varian, one of the present applicants, and is described and claimed in his copending application entitled, "High-frequency tube structure," filed on December 14, 1946. Frequency shift may be brought about from changes in the spacing between grids 8 and 14 due to thermal expansion or contraction. As will be apparent from a study of Fig. 1, such spacing change originates largely from two sources: expansion or contraction of the cylindrical portion 10 bearing entrance grid 8 and expansion or contraction of struts 39 and 41 and associated rough tuning screws 37, 37', 37''. In Fig. 8, there is shown a reflex device with low thermal coefficient of frequency. Resonator 9, coaxial line posts 21, 22, and reflector electrode 18 are shown substantially similar to corresponding parts in Fig. 1. Flanges 29 and 30 may be made of steel, or of other metal of low thermal conductivity, in order to avoid excessive temperature rise of the tuning mechanism thereto attached.

Reentrant portion 10 of resonator 9 continues beyond wall 11 and integrally flares out to flanged portion 60 parallel to flanges 29, 30, tube 10 being of one of the well known high nickel content alloys suitable for butt sealing to certain glasses and having very low thermal coefficients of expansion and preferably having all of its surfaces inside of resonator 9 plated with copper or other highly conducting material. Flange 30 is attached directly to the extended portion of cylinder 10 between resonator 9 and flared portion 60. Struts 61, corresponding to struts 39 and 41 of Fig. 1, are of Invar or other material of low thermal expansion coefficient, as are also screws 37, 37', 37'' engaging these studs. Other parts of Fig. 8 that are similar to corresponding parts of Fig. 1 such as tuning lever 43 and springs 42, 42', 42'' are omitted in Fig. 8 for the sake of simplifying the drawing. Cathode 1, which may be of any of the types to be further described, is placed inside of reentrant portion 10, thus dispensing with grid 5 of Fig. 1, and may be supported in the conventional manner by leads projecting through glass press 63 sealed to cylindrical glass vacuum envelope 62 which, in turn, is butt sealed near the periphery of flange 60.

As shown in the aforementioned Patent No. 2,250,511, the output frequency of a reflex electron beam velocity modulator may be varied by changing the voltage of the reflector plate 18 with respect to exit grid 14. As seen in Fig. 8, a voltage at or very near the cathode 1 voltage may be applied to reflector 18 by lead 64 tapping potentiometer 65 at point 73, the voltage drop across the potentiometer 65 being supplied by battery 66, battery 66 also applying an accelerating unidirectional voltage between cathode 1 and entrance or accelerating grid 8. Any desired modulation may also be applied to the output carrier frequency from resonator 9 by interposing secondary 71 of transformer 68 between tap 73 of potentiometer 65 and reflector electrode 18, and supplying modulation potentials from a suitable source 70 through an amplifier 69 to the primary 72 of transformer 68. This circuit is the invention of Edward L. Ginzton and is described and claimed in his copending application entitled, "High-frequency modulator apparatus," filed on December 14, 1946. The efficiency of operation of such a reflex device may be enhanced somewhat by coating the front surface of reflector electrode 18 with a secondary electron emissive material and moving tap 73 so that reflector 18 is at about half the accelerating voltage. These structures are also the invention of Sigurd F. Varian, and are claimed in his sole application mentioned above.

Suitable cathodes for use in a tube of the type shown in Fig. 8 in which the cathode is mounted adjacent to entrance grid 8 and inside of reentrant tube portion 10 are shown in Figs. 9, 10, and 11. Because of small spaces available in reflex oscillators and amplifiers operating in the region below ten centimeter wavelengths, more conventional types of cathode structures as shown in Fig. 1 may not be desired. A structure which may be more readily adapted to such small spacings is shown in Fig. 9. Thermal conductive rod 74 as of tungsten having a relatively high melting point is positioned coaxially with the axis of the electron beam to be produced. A frustum 75 of a right circular cone with a small diameter end of diameter substantially equal to that of conductor 74 has that small diameter end welded or otherwise secured to the upper end of conductor 74. Frustum 75 may be of nickel or other heat conducting material, and may have its large diameter surface coated with an oxide electron emission material, as at 76. The cylindrical sides of rod 74 are coated with Al_2O_3 or other material of low electrical conductivity at high temperature, as at 87, and around said coating may be wound a coil 77 of heater resistance wire. The heater assembly is surrounded by heat shield 78, which may be a tube of nickel, and which positions the heater assembly by means to be described. Heat shield 78 may have inserted in its lower end a double wall bottom, such as formed by walls 79, 80. Heat shield 78 extends above emitter surface 76 a distance sufficient to give the resultant electron beam a slightly focused quality.

Conducting rod 74 has its lower end terminated

in a cone 81, the apex of the cone being positioned by a dimple in heat shield wall 80. As a point contact only is thus made between rod 74 and end wall 80, very little heat transfer is allowed. The other degree of freedom of motion of the heater structure inside of shield 78 is removed by making the upper sharp edge of the frustum 75 fit into an annular concave groove 82 near the top of heat shield 78 and of substantially arcuate cross-section. Such construction results in a line contact, thus very small heat exchange is allowed between the frustum and heat shield 78. One end of heater coil 77 may be spot welded to heat shield 78, as at 84, while the other end is insulated from heat shield 84 by passing out through holes in walls 79, 80. Leads 83 attached to shield 78 pass through the glass press of the vacuum envelope of the tube and provide a rigid support for the cathode structure, and, together with lead 85, supply necessary heater voltages.

It may be desirable to use a larger wattage heater coil in place of coil 77 of Fig. 9 in which case the structure of Fig. 10 may be used. The conducting member 74 is now extended well past flange 60 and is of diameter more nearly that of the inner diameter of heat shield 78. As it passes beyond flange 60, heat shield 78' is enlarged to fit a cylinder 86 which may also be of nickel and which is closed at its lower end by end wall 88. The portion of conductor 74 covered with Al_2O_3 and heater coil 89 may be equal in diameter to the remainder of rod 74, or may be of somewhat greater diameter, as desired, allowing coil 89 to be more easily assembled and to be of greater power capacity. It is to be understood that heater coils 77 and 89 may be of the coiled coil variety if desired, or may be any type of non-inductive winding.

If frustum 75 and heat shield 78 are both of nickel, welding may result due to the usual high operating temperature of such a cathode at the line contact between frustum 75 and annular groove 82, resulting in increased heat transfer between the cathode and heat shield. The structure of Fig. 11 may be used to remedy this undesired result. The larger diameter of the frustum 75 is made smaller than the inner diameter of heat shield 78 so that three wires 90, 90', 90'' of molybdenum or other suitable material may be inserted between the frustum and the heat shield inner diameter. The wires 90, 90', 90'' may be held in position by pressure only or may be bent into slots cut into the upper face of heat shield 78, as at 91, 91', 91,'' the material of the heat shield adjacent to the slots then being staked to firmly hold wires 90, 90', 90'' in proper placement. The heater assembly may be held in position by a slight tension on lead wires 85, 85', of heater coil 89.

For much shorter output wavelengths, modification of the shape of the resonator may be useful in providing sufficient space for cathode and the reflector electrode, as is shown in Fig. 12. This structure is also the invention of Sigurd F. Varian and is claimed in his above-mentioned sole application. Here resonator 92 is made by turning out of a round conducting disk a cavity having the shape of a frustum of a right circular cone provided with an outer wall 93 and an upper apertured wall 94 which carries exit grid 95 of the resonator 92, i. e. where such grid is used. A flexible conducting diaphragm 96 and reentrant apertured portion 97, which is also the frustum of a right circular cone, form the remainder of the resonator boundary. Reentrant portion 97 carries entrance grid 98, when used, placed concentric with and close to exit grid 95.

Grids 95 and 98 may, as shown in Fig. 13, consist of radial conducting long and short wires 99 and 100. These grid wires may be inserted in wall 94 and reentrant member 97 by milling radial slots in the upper surfaces of 94 and 97, placing the grid wires in the slots in the correct positions, and exerting hydraulic pressure to those faces great enough to cause the surface metal to flow over the wires, thus staking them in position, or by any other method which will leave relatively smooth surfaces after the grids are inserted.

Outside of the resonator, reentrant portion 97 may be extended as a tube 101 and provided with flange 102 to cooperate with flange 103 attached to resonator body 93, said flanges being used with any desired mechanical tuning mechanism, such as that of Fig. 1. The cathode emitter surface 104 is placed close to entrance grid 98, and well inside of tube 101. Cathode 104 may be similar to that shown in Figs. 9 to 11 or of the type shown in Fig. 14 yet to be described, and may be surrounded by a tubular focusing shield 105, which extends past emitter 104 toward grid 98, and which may be supplied with a voltage relative to cathode 104 sufficient to give slight convergence to the resultant electron beam. Focusing shield 105 is supported and supplied with proper voltage by leads 106, which pass through glass press 107. Reflector plate 108 is shown as a flat disk with a short cylindrical wall or flange projecting toward exit grid 95 from the periphery of said disk.

Coupled with resonator 92 by coupling loop 109 is a coaxial line through which ultra high frequency energy may be removed, consisting of small diameter portion 110, tapered portion 111, and larger diameter portion 112 containing a glass seal 113 to provide continuity of the vacuum envelope. All three of the sections have the same inner and outer conductor diameter ratios at any given cross-section in order to avoid impedance lumps in the line. Tapered section 111 is provided so that portion 110 may be of small enough diameter to fit the small resonator 92 used. It is evident that any desired number of such coupling loops and concentric line posts may be provided with any of the structures herein shown.

The modified form of cathode shown in Fig. 14 is adapted for use in structures such as that shown in Fig. 12, which is also Sigurd F. Varian's invention and is claimed in his above-mentioned sole application. This cathode consists of a metal tube 114 which acts as a heat shield, projecting past emitter surface 115 to afford a slight focusing of the electron beam thereby produced, and containing heater coil 116. Emitter surface 115 is made very thin compared to the thickness of tube 114, and may be oxide coated. The cathode assembly is held rigidly by a truss system of wires 117 arranged in V-formations and supported upon the outer conductor 118 of a coaxial line having an inner conductor 119 that is sealed inside of tube 118 by glass to metal seal 120. The tubular outer conductor may be used as one lead to heater coil 116, while inner conductor 119 is used as the other lead to heater 116, the accelerating voltage being applied between 118 and 101.

In low frequency circuit theory it is known that circuits may be made broadly resonant by the introduction of resistive losses into the cir-

cuit in question. This is sometimes useful in lower frequency cases, and, in the instance of ultra high frequency devices of the type herein discussed, the introduction of such losses and the consequent broadening of the resonance curve also has certain applications. As has been shown in connection with Fig. 8, it is possible to tune a reflex device of the type shown in Fig. 8 over a considerable frequency range by varying the reflector electrode potential. If means are introduced to broaden the resonance curve of the hollow resonator used, variation of the reflector potential increases the range over which the device may have a useful output. Referring to Fig. 15, curve 121 depicts the relation between high frequency output and reflector plate voltage, and curve 122 shows the output frequency as a function of reflector plate voltage. As is seen from the curves, when the slope of curve 122 is increased, due to broadening of the resonance curve, the useful flat top portion 123 of curve 121 as included between the dotted lines, corresponds to a larger and larger useful frequency range. In customary terminology, the broadness of a resonance curve is spoken of in terms of Q, which is the ratio of energy stored in the circuit per half-cycle to energy lost per half-cycle in ohmic and radiation or other load losses. Reduction of Q means an increase in loss and a consequent broadening of the resonance curve. Resonators such as 9 of Figs. 1 and 8 or 92 of Fig. 12 may be made of iron or other ferromagnetic material or may have their surfaces roughened or coated with a thin film of a semi-conducting material such as graphite in order to reduce their Q.

Fig. 16 shows a cross-section plan view of a resonator with means for varying Q over a predetermined range as desired. Cylindrical plug 121' may be of graphite or other suitable semiconductor of optimum resistivity and may be projected more or less into resonator 122 by rotation of knob 123' and consequent radial movement of screw 124 which is threaded into end plate 125. Plate 125 closes the outer opening of tube 126, whose inner end terminates at resonator 122'. Glass envelope 127 is provided to prevent leakage around screw 124. As seen, antenna coupling loop 128 is perpendicular to the plane of the figure.

For shorter wavelength resonators, such as that of Fig. 12, the construction shown in Figs. 17 and 18 may be used. This is the sole invention of Arthur E. Harrison and is described and claimed in his copending application entitled, "High-frequency tube structure" filed on December 14, 1946. The round flexible diaphragm 96' is now extended nearly to the periphery of resonator body 93. Two metal portions 129, 129' are inserted oppositely against walls 93 and 94, leaving a small space free above flexible diaphragm 96' to allow motion of the diaphragm. The resultant elimination of complete axial symmetry in the resonator produces a corresponding reduction in Q. It is to be understood that the structure shown in Figs. 17 and 18 may be greatly varied, and that these figures are intended only to be illustrative of the present invention.

A modified reflector electrode is shown in Fig. 17. This is also the invention of Arthur E. Harrison, claimed in his above-mentioned copending sole application. It consists of disk 130 operated at or near the potential of cathode 105, and of a surrounding concentrically placed focusing ring 131 which imparts a slight focusing effect to the electrons on the return trip toward grid 95 so that a lesser portion of the returning electrons strike wall 94.

Another device for decreasing the Q of a resonator is shown in resonator 134 of Fig. 19. Stretched parallel to flexible diaphragm 132 are a plurality of wires 133, being fastened at one of their ends to tubular conducting wall 135 and at their other ends to the tubular reentrant portion 136 of resonator 134. Wires 133 have a resistance depending upon the desired shunt impedance, the geometry of the resonator, and the placement of the wires therein.

It is found that for reflex devices of the above type, and especially for shorter wavelength tubes, it becomes desirable to maintain grids 136', 137 always parallel so that the associated cathode and reflector electrode structures remain in alignment, as shown in Fig. 19 which is the invention of Sigurd F. Varian, and is claimed in his above-mentioned copending sole application. Wall 135 and tube 136 of the resonator are considerably extended, and a second flexible diaphragm 138 is used to close the open end of tube 135. Pressure exerted by a tuning lever 43 of a mechanical tuning mechanism which may be similar to that of Fig. 1 forces tube 135 to always move parallel to tube 136, thus maintaining grids 136' and 137 parallel. This method of construction is seen to eliminate some of the complexity of the tuning device, and is seen to also be useful with two resonator electron beam velocity modulating devices.

To obtain perfect alignment of grids 136', 137, cathode 139, and reflector electrode 140, it may be desirable to provide adjustment means for positioning the cathode and reflector. Resonator 134 has its upper wall 148 extended to form flange 141. Mounted above wall 148 is tube 142 which carries in its open end apertured flexible diaphragm 143. Mounted in the central aperture of diaphragm 143 is tube 144 which is sealed to glass insulator 145 which supports conductor 149 on which reflector electrode 140 is mounted. Tube 144 also carries flange 146, parallel to and spaced from flange 141. Three screws 147 are mounted at 120° intervals to rotate freely in holes near the periphery of upper flange 146. The other ends of screws 147 are threaded into flange 141, and thereby afford means of adjustment to secure parallelism between exit grid 137 and reflector 140 and the proper spacing of these elements.

Cathode 139, which is mounted on concentric line 150 which projects through glass insulator 151 in the manner described in connection with Fig. 14, and which extends up into the reentrant tube 136, may be similarly adjusted by the action of three spaced screws 152 cooperating with flanges 153 and 154 to cause motion of flexible diaphragm 155.

It may be desired to provide the flexible diaphragm means 143, 155 for preliminary adjustment of cathode and reflector spacings at the factory, also providing means to prevent possibility of misalignment at a future date. As seen in Fig. 20 (which is also the invention of Sigurd F. Varian claimed in his above-mentioned copending sole application) in an illustration showing the method as used only on the reflector end of the tube, flanges 141 and 146 and cooperating screws 147 of Fig. 19 are dispensed with. Tube 142 is made to extend well above flexible diaphragm 143, as at 157. After alignment of reflector plate 143 and grid 137 solder or other low melting alloy 156 may be poured into the volume

dained by tube 157, diaphragm 143, and tube 144. After the alloy cools, the jig or other clamping device used in determining the optimum position of the reflector plate may be removed, the alloy thus securing the position of reflector 140. A similar procedure may be used in permanently positioning cathode 139 of Fig. 19.

In the structure of Fig. 19, or in other similar devices using external resonant members cooperating with an electron beam, the mechanical lever 43 may be replaced by the device shown in Fig. 24. Rough adjustment screw 215 is shown threaded through thermal insulating bushings 217 in bracket 216 attached to resonator wall 135, and is held in place by nuts 218 and 219 threaded thereon. Similarly, screw 220 is mounted in insulating bushings 221 in flange 153, being locked in place by nuts 222 and 223. Screws 215 and 220, facing oppositely, are joined by thin-walled tube 224, which may be coated on its outside with a layer 225 of Al_2O_3, and wound with resistance heater wire 226, which may be supplied with a variable amount of current from battery 227 and rheostat 228. Heat radiation may be used to heat tube 224, instead of conduction through Al_2O_3 layer 225, as by supporting heater wire 226 inside of thin-walled tube 224 if desired. It will be apparent that many other devices, directly electrically controllable, may be used in place of the thermal device here shown to produce predictable changes in the spacing between flanges 216 and 153, and thus to produce changes in the natural frequency of an associated hollow resonator, such as magnetostrictive or piezoelectric or other well known means.

Another form of the thermal tuning device is shown in Fig. 25. Thin-walled tube 240 is attached at right angles to flange 216 at 241 and extends through an aperture in flange 153, ending in internally threaded portion 242. Screw 243 which fits into the internal thread 242, acts as a rough adjustment device, and is free to rotate only in end plate 244. End plate 244 closes the outer end of the tube 245, which is concentric to and surrounds thin-walled tube 240. Tube 245 is fastened to flange 153, and extends through flange 153 to almost touch flange 216. Thin-walled tube 240 contains a loop of resistance heater wire 246, to the terminals of which may be applied the adjustable controlling voltage. With heat being applied to it from wire 246, thin-walled tube expands or contracts with a minimum of time delay due to its thinness and large radiation surface. Tube 245 is preferably of Invar or other low thermal expansion coefficient metal, and acts to shield tube 240 from sudden temperature changes due to drafts. The subject matter of Figs. 24 and 25 is the joint invention of John R. Woodyard and Sigurd F. Varian and is claimed in their copending application, Serial No. 513,090, filed December 6, 1943.

Another arrangement that provides parallel motion of the resonator grids of the reflex type tube is shown in Fig. 21. The tube may be similar to that shown in Fig. 1 and consists of end bell 158 containing the cathode structure, resonator 159, tube 160 containing the reflector electrode supported by glass end bell 161. Facing and soldered to end wall 162 of cathode end 158 is an apertured disk 163, which has an internally threaded tubular portion 163' provided at its periphery, through which coaxial line 164 may extend. Threaded to tubular portion 163' is a hollow cylinder 165, which has centrally located on its cylindrical sides, elongated holes 166 whose

major axes are parallel to the axis of the tube. The upper end of the casting 165 has an apertured top portion 167 containing apertured bushing 168 which is internally threaded.

Tube 160 has attached concentric to it threaded flange 170 which supports a cylindrical casting 171 with top portion 172 integrally attached. Casting 171 may have elongated holes 173 similar to those of casting 165, and top 172 contains a centrally located apertured bushing 174 which is also internally threaded. Bushing 168 projects through a hole in a panel 175, on which the device may be mounted, said bushing being of diminished diameter where it extends through panel 175 and being supplied with lock nuts 176 and 177 on the side of panel 175 opposite to the reflex tube.

Projecting through bushing 168 is a threaded shaft 178 which mounts knob 179 having index marks 180 cooperating with index marks on concentric tube 181 also held fixed to panel 175 by nuts 176 and 177. Threaded portion 182 of shaft 178 screws into bushing 168, shaft 178 being further extended toward the reflex tube as a smaller threaded portion 183, which, in turn, threads into bushing 174 of casting top 172. Shaft portion 182 is provided with a right-hand thread of one pitch, and shaft portion 183 with a left-hand of lesser pitch, so that a differential screw is provided, whereby rotation of knob 179 causes a very small change in the distance between bushings 168 and 174, consequently causing an equally very small change in the distance between the resonator grids. It is seen that air may be forced in through holes 166 and 173 on one side of the tuner by a suitable blower, around the electron tube, thereby cooling it, and out through holes 173, 166 on the opposite side of the tuner, if desired. This structure is the invention of Edward L. Ginzton and is claimed in his above-mentioned copending sole application.

As disclosed in United States Letters Patent No. 2,280,824, the resonator of an electron beam velocity modulation tube may be applied externally to the vacuum envelope. Figs. 22 and 23 illustrate an improvement in such a device. Resonator 182 is coupled by capacitative concentric tubes 183 and 184, which may be of nickel, to exit grid 185, which may be of copper, through vacuum envelope 189, which may be of quartz or low loss glass; and is also seen to be coupled by capacitative concentric tubes 186 and 187 through vacuum envelope 189 to entrance grid 188. Vacuum envelope 189 supports cathode 190 near entrance grid 188 and reflector electrode 191 near exit grid 185. Cathode 190 is supported by insulator 191' and leads 192 which pass through glass press 193. Tubes 184 and 187 are positioned and grounded or held at desired potential by leads 230, 231, respectively.

Serious loss of energy which may result by leakage of energy out through the vacuum envelope from between the capacitative elements coupling the resonator and grids is prevented in the present construction. Tubular wall 196 of resonator 182 is extended in both directions, to form the outer wall of cavities 197, 198 on each side thereof. The ends of cavities 197, 198 are closed by apertured round end plates 199, 200, respectively, tubes 201, 202, which just slide over the outer diameter of vacuum envelope 189, being fastened to apertured disks 199, 200, respectively, so that a portion of each tube 201, 202 extends into cavities 197, 198 and a portion extends on past disks 199, 200, respectively. Inner capacitative ele-

ments 184 and 187 are extended toward opposite ends of the vacuum envelope to end even with the outside ends of tubes 201, 202, respectively. Tubes 201, 183, 186, and 202 are each made substantially electrically a quarter wavelength long, the distance between tube 201 and tube 183 and that between tubes 186 and 202 also being substantially electrically equal to a quarter wavelength.

Consider the impedance looking from grid 188 down the concentric line thus formed by tube 187 and the externally attached resonator and filter system. The impedance at point 203 (the outer edge of tube 202) is largely resistive. Let it be designated by R. Due to the presence of R, if Z_1 is the impedance of the section of line defined by tube 202, the impedance seen looking from point 204 toward point 203 is

$$\frac{Z_1^2}{R}$$

If the characteristic impedance of cavity 198 be called Z_2, the impedance at point 205 looking toward point 204 is

$$\frac{Z_2^2 R}{Z_1^2}$$

Since the tubes 202 and 186 are of equal cross-section, the impedance of the section of line defined by tube 186 may also be called Z_1. Then the impedance at point 206 is seen to be:

$$\frac{Z_1^2 . Z_1^2}{Z_2^2 R} \text{ or } \frac{Z_1^4}{Z_2^2 R}$$

In general, the filter structure shown in Fig. 9 may be designed so that this impedance may be made small, as, for a given R, Z_1 may be made small and Z_2 large, so that little or no energy can leak down vacuum envelope 189 to escape. Exactly the same reasoning holds to prevent leakage out of the reflector plate end of the device.

If desired, the vacuum envelope may have a graded seal at 207, thus changing from the low loss quartz of tube 189 to a glass for cathode envelope 210 which is more suitable for use in press 193. Fig. 23 shows a cross-section of resonator 182 of Fig. 22 turned 90°. The concentric line 211 bearing coupling loop 212 is shown insulated from wall 196 of resonator 182 by means of insulating bushing 213, so that, if desired, resonator 182 may be held at any desired potential relative to coaxial line 211. Tuning of resonator 182 may be accomplished by rotation of screw 214, as disclosed in the aforementioned Patent No. 2,259,690. Similar screws or other tuning means may be provided in semi-resonant cavities 197, 198, if desirable.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A high frequency tube structure and mounting comprising a panel, a cavity resonator having relatively movable parts for the tuning thereof, a bracket fixed to one portion of said resonator and adapted to be mounted in said panel, movable means passing through said panel and mounted in said bracket for actuation from the opposite side of said panel from said bracket, and frequency control means connected to and operated by said movable means for tuning said resonator, whereby a unitary tuning and mounting mechanism is provided.

2. A tuning and support mechanism for tuning a high frequency tube structure having a cavity resonator with relatively movable frequency-determining portions and for mounting said structure on a panel, said mechanism comprising a bracket adapted to be fixed to one portion of said resonator and adapted to be mounted on said panel, movable means mounted in said bracket and adapted to pass through said panel for actuation from the side of said panel opposite said bracket, and frequency control means connnected to and operated by said movable means and adapted to tune said resonator, whereby a unitary tuning and mounting mechanism is provided.

3. A high frequency tube structure comprising a cavity resonator having a movable wall provided with an apertured portion and also having a rigid wall opposite said movable wall and provided with an aperture, a base secured to one of said walls, means carried by said base and aligned with said resonator for producing and projecting a stream of electrons through said resonator by way of said apertures, a reflecting electrode secured to the other of said walls at the exterior of said cavity resonator for redirecting electrons thereinto, and adjustable means operably interconnected between said base and said other wall for varying the spacing between said walls to provide tuning of said resonator.

4. Frequency control apparatus comprising a hollow resonator device having two relatively movable frequency-determining parts mounted in spaced relation, means for relatively displacing said parts substantially along a predetermined path comprising a bent lever pivotally connected to one of said parts and rockable about an axis which is disposed at an angle with respect to said path, and strut means operably connected between said lever and the other part.

5. Frequency control apparatus comprising a hollow resonator device having two relatively movable frequency-determining parts mounted in spaced relation longitudinally of said device, and means for regulating the spacing of said parts comprising a bent lever rockable about a transverse fulcrum fixed with respect to one of said parts, motion transmitting strut means interposed between said lever and the other part, and means in said apparatus for moving said lever about its fulcrum.

6. The apparatus defined in claim 5, including a bracket rigid with said one resonator part, and wherein said means for moving the lever about its fulcrum is a micrometer assembly mounted on said bracket.

7. Frequency control apparatus comprising a hollow resonator device having two relatively movable frequency-determining parts mounted in spaced relation, a lever provided with two angularly disposed arms, means in said apparatus providing a pivotal connection between one of said arms and one of said parts, motion transmitting means between said one arm and said other part, and means in said apparatus operatively coupled to said other arm for moving said lever about its pivot.

8. The frequency control apparatus defined in claim 7, wherein said relatively movable parts are displaceable in a direction substantially longitudinally of said device, and said lever pivots about a transverse axis in said apparatus.

9. Electron discharge apparatus comprising a hollow resonator, means adjacent said resonator

for projecting a stream of electrons through said resonator, frequency control means operably connected to said resonator comprising two relatively movable members, and means for effecting relative movement of said members comprising a bent lever pivotally connected to one of said members, a strut extending between said lever and the other of said members substantially parallel to said electron stream, and a control member operatively coupled to said lever and movable in a direction angularly disposed with respect to said stream.

10. Frequency control apparatus for a hollow resonator device having frequency-adjusting means comprising a rigid bracket having a first arm adapted to be fixed to said device and a second arm extending at an angle with respect to said first arm, a control member adjustably mounted on said second arm and adapted to coact with said frequency-adjusting means, and means coupled to said member for measurably adjusting said control member.

11. The control apparatus defined in claim 10, wherein said means for adjusting said control member comprises a micrometer screw assembly.

12. The control apparatus defined in claim 10, including means on said second arm for attaching said bracket to a supporting panel or the like.

13. Frequency control apparatus for a hollow resonator device comprising a substantially L-shaped bracket, means on an arm of said bracket for fixing said bracket to said device, an axially adjustable member mounted on the other arm of said bracket, and a micrometer assembly supported on said other arm and operatively connected to said member for measurably adjusting said member.

14. Frequency control apparatus comprising a hollow resonator device provided with spaced electron-permeable walls, radially extending flanges on said device rigid with the respective walls, springs interconnecting said flanges, a lever pivoted on one of said flanges, strut means between the lever and the other of said flanges, a bracket rigid with said one flange, and means on said bracket adjustable for moving said lever about its pivot.

15. Electron discharge apparatus comprising a base structure, a hollow resonator mounted on said base structure and provided with aligned adjustably interconnected electron-permeable walls, one of said walls being rigidly secured to said base structure, cathode means in said base structure for projecting a stream of electrons through said walls to couple said stream with the resonator, an electron-reflecting electrode mounted in said apparatus beyond said resonator for returning electrons of said stream into said resonator, and adjustable strut means interconnecting said base structure and that part of said resonator which is rigid with the other of said walls for varying the spacing between said walls for tuning said resonator.

16. Electron discharge apparatus comprising a base structure, a hollow resonator mounted on said base structure and provided with aligned adjustably interconnected electron-permeable walls, means rigidly securing said base structure to one of said walls, cathode means in said base structure for projecting a stream of electrons through said walls to couple said stream with said resonator, an electron-reflecting electrode mounted in said apparatus beyond said resonator for returning electrons of said stream into said resonator, and spring-biased adjustable strut means interconnecting said base structure and that part of said resonator which is rigid with the other of said walls for varying the spacing between said walls.

17. Electron discharge apparatus comprising a hollow resonator body having an end wall rigid with said body and formed with a first electron-permeable wall portion, a flexible wall at the other end of said body, a hollow pole carried by said flexible wall and projecting into said resonator and having an electron-permeable end portion adjacent to and aligned with said first wall portion, a base secured to said pole, a reflector electrode mounted on said resonator body in alignment with said wall portions, a cathode carried by said base for projecting a stream of electrons through said wall portions toward said reflector, and means operably interconnected between said base and said resonator body for varying the spacing between said wall portions.

18. The electron discharge apparatus defined in claim 17, wherein said last means includes a bracket secured to said base, pivoted lever and strut means interposed between said base and resonator body, and means on said bracket for adjusting said lever and strut means.

19. High frequency electron discharge tube structure comprising means defining a hollow resonator having opposed walls formed with aligned electron-permeable sections, a base structure rigid with one of said sections, an electron reflector electrode aligned with said sections and rigid with the other of said sections, and frequency control means operably interconnected between said base structure and that portion of said resonator rigid with said other section and providing relative adjustment between said one section on the one hand and said reflector and said other section on the other hand.

20. The high frequency tube structure defined in claim 19, wherein one of said walls is formed with a reentrant part having an electron-permeable section near the electron-permeable section in the other wall, and wherein one of the resonator walls is formed with a flexible portion enabling said adjustment.

21. High frequency tube structure comprising a resonator body having flexibly connected opposed spaced electron-permeable wall portions, a base structure rigid with one of said wall portions, means supported by said base structure for projecting an electron beam through said wall portions, frequency control means operably connected between said base structure and that portion of said resonator body which is rigid with the other of said wall portions for varying the spacing of said wall portions and hence the frequency of said resonator, insulator support means rigid with said resonator body, and a reflector electrode mounted on said support means for returning said beam into said resonator.

22. High frequency tube structure comprising a rigid cup-shaped resonator body member, a flexible wall closing the end of said body member, said body member and wall being apertured in alignment, a base structure, means aligned with said apertured member and wall and carried by said base structure for projecting an electron beam through the apertures of said apertured member and apertured wall, a reflector electrode located along the path of said beam for returning said beam into said resonator, insulation support means rigid with said resonator body member mounting said reflector electrode, and adjustable means connected between said resonator

body member and said base structure for varying the frequency of said resonator.

23. High frequency tube structure comprising a hollow resonator having a flexible wall portion and a rigid end wall portion, said wall portions having substantially aligned apertures, means aligned with said apertures for projecting an electron stream between said apertures for interaction with an oscillatory field within said resonator, and a tubular high frequency transmission line extending substantially parallel to the path of said electron stream and having an end secured in an aperture in said rigid wall portion.

24. Electron discharge apparatus comprising a hollow resonator body having an apertured end wall rigid with said body, an apertured flexible wall at the other end of said body, a hollow pole carried by one of said walls and projecting into said resonator and having an electron-permeable end portion adjacent to and aligned with the aperture in said other wall, a base structure secured to said pole, a reflector electrode mounted on said resonator body in alignment with said

walls, a cathode carried by said base structure for projecting a stream of electrons through said walls toward said reflector, and means operably interconnected between said base structure and said resonator body for varying the spacing between said walls.

25. High frequency tube structure comprising means defining a hollow resonator having a rigid wall portion and a flexibly mounted wall portion, means providing an entrance aperture in one of said wall portions and a spaced aligned exit aperture in the other wall portion, means adjacent said resonator for projecting an electron beam through said apertures, a reflector electrode mounted in the path of said beam to return said beam through said exit aperture into said resonator, means fixedly interconnecting said reflector electrode with said rigid wall portion, and tuning means connected to said wall portions for controlling the spacing of said apertures.

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