

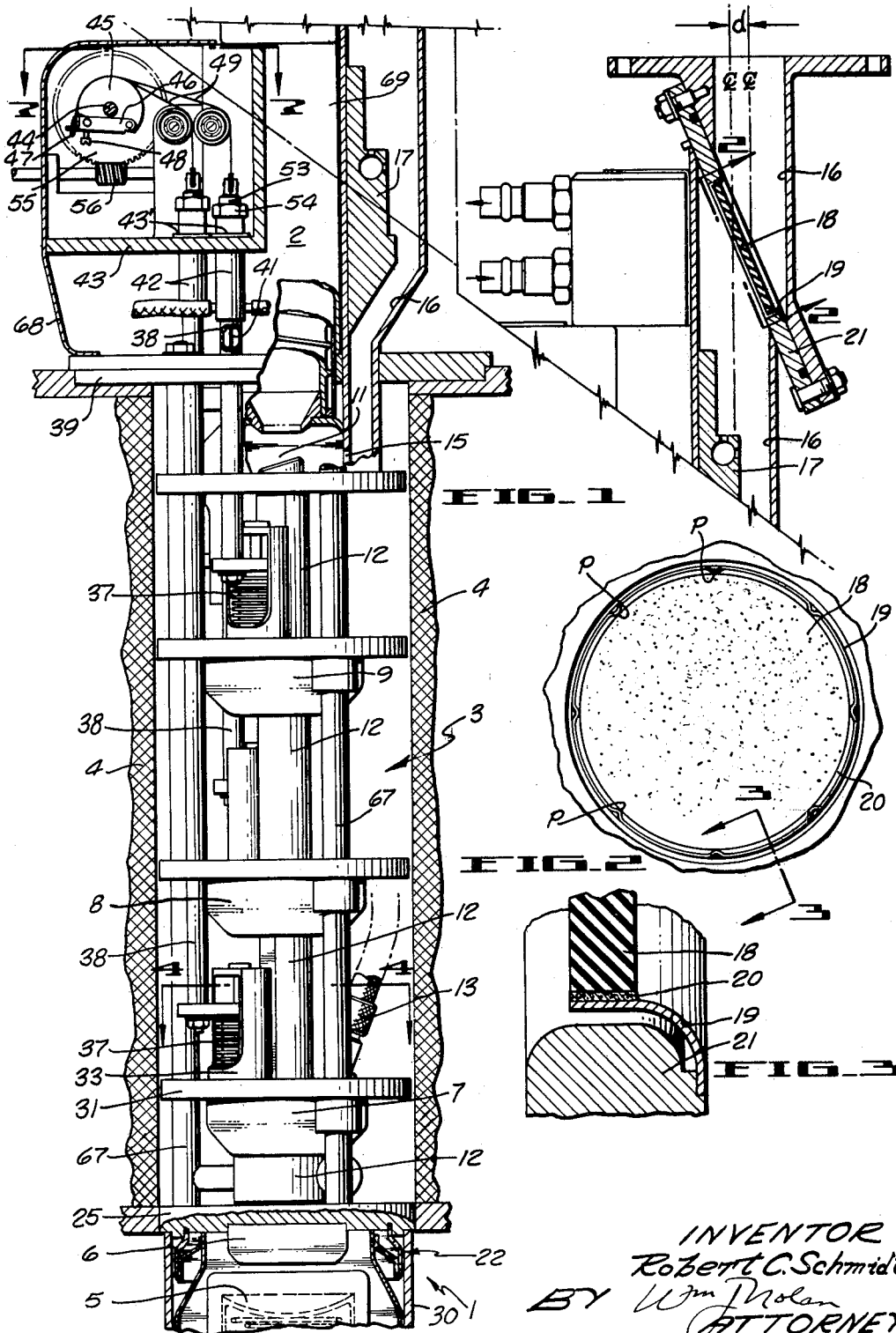
May 5, 1964

R. C. SCHMIDT
HIGH FREQUENCY INDUCTIVELY TUNABLE VELOCITY
MODULATION TUBE APPARATUS

3,132,280

Original Filed Nov. 14, 1955

3 Sheets-Sheet 1



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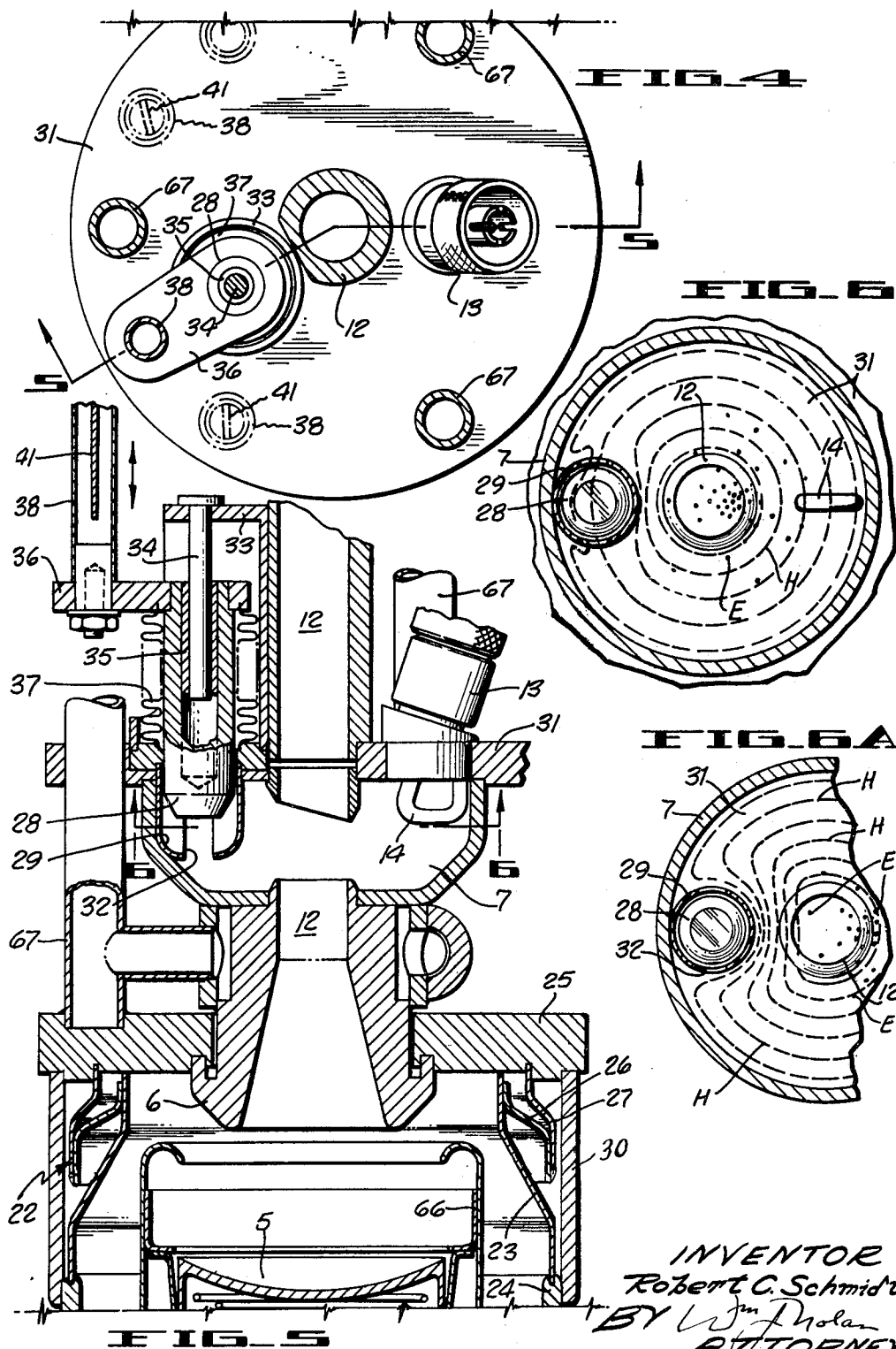
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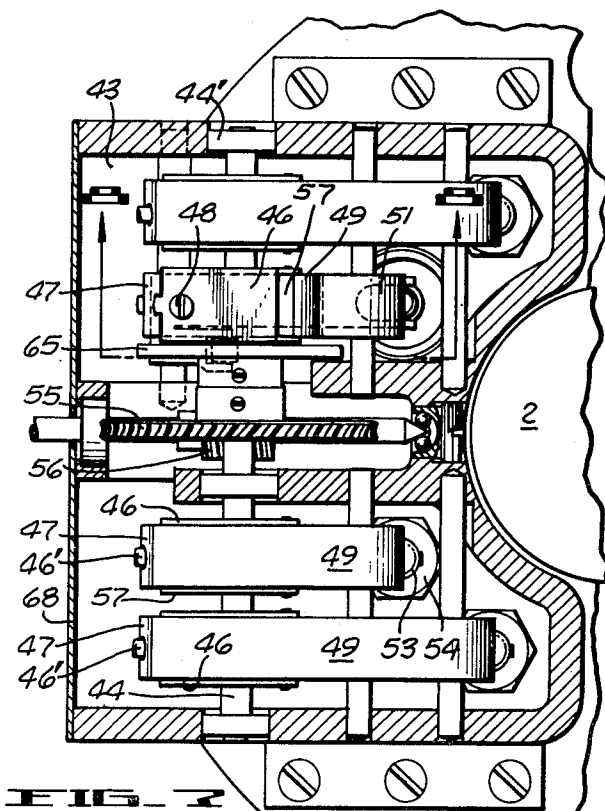


FIG. 7

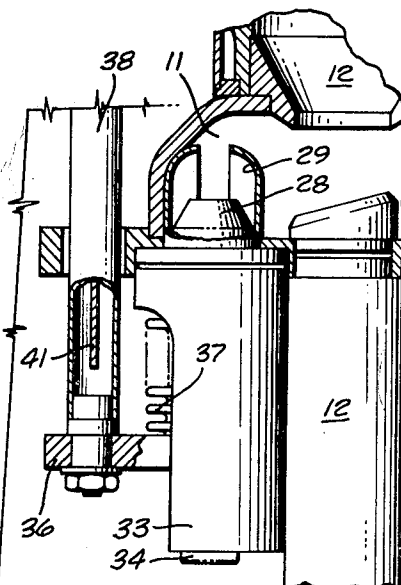


FIG. 9

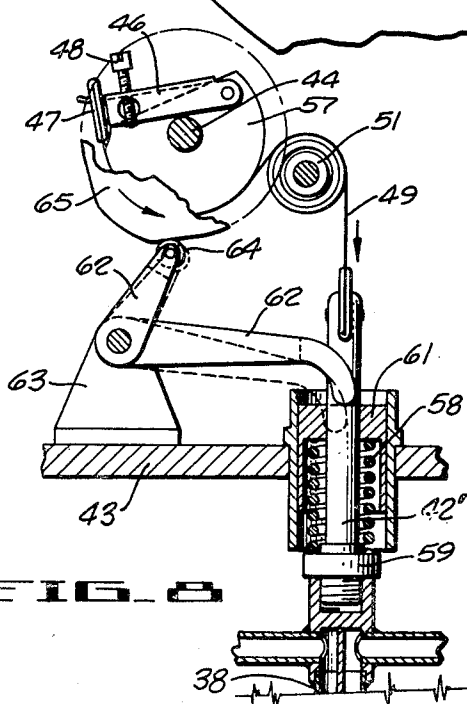


FIG. 8

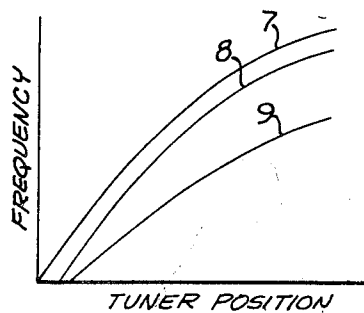


FIG. 10

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3,132,280

HIGH FREQUENCY INDUCTIVELY TUNABLE VELOCITY MODULATION TUBE APPARATUS

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Original application Nov. 14, 1955, Ser. No. 546,624, now Patent No. 2,939,036, dated May 31, 1960. Divided and this application Apr. 4, 1960, Ser. No. 19,708
9 Claims. (Cl. 315-5.47)

This invention, a division of co-pending application, Serial No. 546,624, filed November 14, 1955, now U.S. Patent No. 2,939,036, granted May 31, 1960, relates in general to electron tube apparatus and more specifically to a novel improved electron tube apparatus of the velocity modulation type employing cavity resonator devices as, for example, high power klystron tubes utilized in systems employed in radar, linear accelerators, navigation beacons, microwave transmission, etc.

The life of a high power tube, heretofore, has been seriously limited by the unreliability of output windows. Failure of the output window normally causes a leak allowing the vacuum within the tube to go up to atmospheric pressure thereby rendering the tube inoperative and permanently damaging the cathode necessitating its replacement. Also, the major cause of a tube falling below specification after its normal expected life in operation is the exhaustion of its cathode.

It has been found that many tubes may be returned to active use by merely replacing the cathode and, therefore, a practical manner of easily removing and replacing the cathode sections of such high power tubes has been sought.

High power multi-cavity amplifiers have been heretofore built having the individual cavities tunable but thus far the cavities have been separately tuned, that is, tuned with separate tuning controls. This requirement of being separately tuned has been due to the lack of a suitable tuning device possessing a linear frequency versus position characteristic which could be ganged together. The present invention provides such a linear tuner and effectively gangs the tuners whereby the multi-cavity tube may be tuned with a single control.

It is, therefore, the principal object of the present invention to provide a novel high-power, high-gain electron tube apparatus which is relatively compact in construction and which offers gang tuning, long life, easy maintenance and electrical stability.

One feature of the present invention is a novel cathode take-apart joint allowing the cathode to be removed and reassembled easily without destroying the previously acquired alignment.

A further feature of the present invention is a novel gang tuning mechanism which provides a means for simultaneously tuning each cavity resonator and includes means for compensating for different tuning rates of the individual cavities.

Other features and advantages of the present invention will become evident upon a perusal of the following specification taken in connection with the accompanying drawings wherein,

FIG. 1 is a longitudinal elevational view of the novel tube apparatus of this invention shown partly in section, the top portion of the tube being offset to the right in this view and the well-known focusing magnet and cathode structure of this tube apparatus being shown only fragmentarily,

FIG. 2 is an enlarged elevational view of a portion of the structure of FIG. 1 taken along line 2-2 looking in the direction of the arrows,

FIG. 3 is an enlarged fragmentary cross sectional view

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of a portion of the structure of FIG. 2 taken along the line 3-3 in the direction of the arrows,

FIG. 4 is an enlarged cross sectional view of a portion of the structure of FIG. 1 taken along line 4-4 in the direction of the arrows,

FIG. 5 is a longitudinal cross sectional view of the structure of FIG. 4 taken along line 5-5 in the direction of the arrows,

FIG. 6 is a transverse cross sectional view of a portion of the structure of FIG. 5 taken along line 6-6 in the direction of the arrows showing electric and magnetic lines,

FIG. 6A is a partial view of a structure similar to FIG. 6 having the tuning plunger fully extended,

FIG. 7 is an enlarged transverse section view of a portion of the structure of FIG. 1 taken along line 7-7 in the direction of the arrows,

FIG. 8 is a longitudinal cross sectional view of a portion of the structure of FIG. 7 taken along line 8-8 in the direction of the arrows,

FIG. 9 is an enlarged longitudinal part cross sectional view of a portion of the output cavity resonator structure of FIG. 1 including a portion of the tuning rod, and

FIG. 10 is a graph of frequency versus tuner position characteristics for a plurality of cavity resonators.

The construction of the novel tube apparatus will now be described with reference to the drawings followed by a description of its operation.

Shown at the bottom of the depicted structure in FIG. 1 is a partial view of a cathode assembly 1. At the other end of the structure is a collector assembly 2 and interposed between the cathode assembly 1 and the collector assembly 2 is a radio frequency section 3. Surrounding the radio frequency section is a magnetic beam confining and focusing solenoid 4.

The cathode assembly 1 contains an electron emissive element or cathode 5 which in use provides a ready source of electrons. A positive potential with respect to the cathode 5 is applied to an apertured anode 6 (FIGS. 1 and 5). The electric field thus established between the cathode 5 and anode 6 accelerates the electrons to a high velocity and draws them through the apertured anode 6 toward the collector 2.

Successively arranged between the cathode 5 and collector 2 in the R.F. section 3 are a plurality of cavity resonators, input resonator 7, first buncher cavity 8, second buncher cavity 9 and output cavity 11. Mutually spaced apart drift tube sections 12 interconnect the cavity resonators and provide interaction spaces or gaps within the respective cavity resonators. A signal-input coaxial line 13 is coupled into the input cavity 7 by coaxial loop 14 (FIG. 5).

The output cavity resonator 11 is coupled to the load through an output iris 15, an output waveguide 16 which incorporates a waveguide impedance transformer 17, and output window 18.

The conventional three step binomial impedance transformer 17 has been disposed outwardly of the output iris 15 thereby allowing a shallow high admittance section of output waveguide 16 to be employed in the immediate vicinity of the output cavity 11. The shallow section of waveguide 16 is then brought away from the output iris 15 parallel to the longitudinal axis of the tube apparatus whereby the R.F. section diameter is kept to a minimum in the vicinity of the output cavity 11, thereby allowing the beam confining solenoid 4 to extend upwards of the tube apparatus adjacent the initial portions of the collector 2. Carrying the confining solenoid 4 up to and around the collector region minimizes beam interception in the output cavity and collector entrance whereby unwanted secondary emission in this vicinity is kept to a minimum.

A novel output window assembly is shown in FIGS. 1,

2 and 3 which comprises the disk-shaped output window 18, as of alumina ceramic, sealed to an annular flanged window cup 19. The flanged portion of the window cup 19 is fixedly held by an apertured window frame member 21. The window frame member 21 is secured transversely in the output waveguide 16. The flanged window cup 19 has a plurality of indentations or dimples P equally spaced around its perimeter. The indentations extend inwardly a distance of approximately 0.003" and make physical contact with the metalized edge of the ceramic window 18 thus providing a 0.003" gap between the metalized ceramic and the window cup 19. A solder alloy 20 such as, for example, copper-gold is disposed between the ceramic window and the window cup and alloys with the metalized ceramic and the window cut 19 thereby forming a vacuum-tight ductile seal. The window cup member 19 is made relatively thin, for example, approximately 0.020". The cup is made thin to prevent undue stress on the ceramic-to-solder-to-cup seal caused by differential coefficients of thermal expansion of the ceramic, solder and cup members.

The window cup 19 may be made of a ductile material as of, for example, copper or it may be made of a copper coated less ductile but stronger material as of, for example, iron or nickel. The copper coating is provided to assure high electrical and thermal conductivity of the seal and cup member 19 whereby R.F. heating in the joint is minimized and in addition heat generated in the ceramic may be conducted away.

The thickness of the solder 20 must be accurately controlled because the forces exerted on the adjacent bonds between the joined elements vary as the mass of the joined materials. For example, in the ceramic-to-cut joint as shown in FIG. 3, if the thickness of the solder 20 is allowed to be come too thick, for example, in excess of 0.005", the force exerted as the temperature rises, in use, may cause a failure of the ceramic or a failure in the solder-to-ceramic or solder-to-cup bond. The indentations P have been provided to assure proper centering of the ceramic window 18 within the window cup 19 thereby controlling the solder thickness and preventing uneven solder thicknesses about the periphery of the ceramic window 18.

The output waveguide 16 (FIG. 1) has been offset outwardly of the output window 18. It has been found that power reflections from the window assembly are substantially eliminated over a broad band of frequencies by providing a certain amount of offset between the axial center lines of the segments of waveguide abutting the window assembly and the center of the circular window. In the present tube apparatus it has been found that an offset of approximately 0.325" substantially eliminates power reflections over the frequency range of the tube. However, the amount of offset required for different tubes will vary. The dimensions given here are to be considered only exemplary and not in a limiting sense.

In addition it has been found that power reflections from the window assembly may be further reduced by adjusting the geometric center of the dielectric window such that it is slightly radially displaced from the axial center line of the adjoining segment of waveguide 16 on the tube side of the window 18.

Referring now to FIGS. 1 and 5 there is depicted a novel cathode take-apart joint 22 comprising a first hollow modified frusto conical member 23 held at its large diameter by the end of a hollow cylindrical cathode envelope segment 24. The other or narrow diameter end of the first conical member 23 abuts an annular cathode pole piece or transverse header 25 thereby establishing the longitudinal positioning of the cathode assembly 1. A second hollow modified frusto conical member 26 is secured to the outer wall of the first conical member 23 at its small diameter portion and extends downward and is spaced from said first conical member 23 at its larger diameter portion. A third modified frusto conical member 27 is secured at its narrow diameter to the cathode pole piece 25 and extends down around the second conical

member 26. A portion of the inside surface of the third conical member 27 abuts a portion of the outside surface of the second conical member 26. These abutting surfaces provide a transverse cathode aligning interface and are secured together in a vacuum-tight manner as, for example, by a running weld at their overlapping ends.

This novel take-apart joint provides an easy means for achieving transverse and longitudinal alignment of the cathode assembly. The cathode assembly may be removed by turning the weld off in a lathe after removal of split cover 30. In reassembling the tube the cathode need only be assembled and then rewelded. The proper alignment is retained.

The cavity resonators 7, 8 and 9 have novel tuner assemblies of similar design associated therewith, the tuner assembly of cavity resonator 7 being shown in detail in FIG. 5. A tuning plunger 28 of a good heat and electrical conductive material as of, for example, copper and having an axial bore therein protrudes into the input cavity resonator 7. A capacitive plunger shield 29 is fixedly mounted to a flat end wall 31 of the cavity resonator and surrounds the inner end of the movable tuning plunger 28, a slot 32 being provided in the capacitive shield to permit magnetic coupling to the space inside the shield 29.

A hollow open-sided cylindrical tuner guide support 33 is secured at one end to the outside surface of the flat cavity end wall 31 and extends longitudinally of the tube parallel to the drift tube 12. A cylindrical plunger guide rod 34 is fixedly secured at one end in the tuner guide support 33. A hollow cylindrical plunger bearing 35 as of, for example, oil impregnated brass is mounted within the plunger bore and slideably bears on the plunger guide rod 34 thereby assuring a precisely controlled rectilinear travel of the tuning plunger 28. A tuner actuating arm 36 is secured to the outer end of the tuning plunger 28 and extends substantially perpendicular thereto. A flexible metallic bellows 37 as of, for example, non-magnetic stainless steel is interposed between the actuating arm 36 and the flat cavity end wall 31. A vacuum-tight seal is made at both ends of the bellows 37 where the bellows joins the actuating arm 36 and cavity wall elements whereby a vacuum may be maintained within the tube apparatus while allowing for travel of the tuning plunger 28.

The capacitive shield 29 has been made concentrically symmetrical with respect to the tuning plunger 28 to prevent the excitation of coaxial electromagnetic modes in the end of the plunger surrounded by the bellows 37. If these coaxial modes are excited the currents induced in the plunger and its associated members are likely to produce excess heating resulting in failure of certain bonds, melting of the bellows, and the like. Moreover, the length of the bellows 37 and plunger 28 should be made such as not to have a resonant mode in the tuning range of the cavity resonator. The inner end of the plunger 28 has been beveled to reduce the capacitance between it and the shield 29. In the instant case this particular resonator operates in a mode such that the H fields are distorted circular paths in a plane transverse to the longitudinal axis of the tube (see FIG. 6). This requires that the slot 32 lie along a plane substantially parallel to the circumference of the resonator.

The capacitive plunger shield 29 operates such as to minimize the capacitive effects of the plunger. The resonant frequency of a cavity resonator device is approximately found from the following relationship:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

The conductive plunger 28 of the present invention operates upon the inductive portion of the cavity resonator or L in the above formula. However, without the capacitive shield of the present invention, movement of the plunger would also substantially operate upon the capacitance or C of the above formula. It so happens that without the shield 29 the inductive action of the plunger is offset by

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its capacitive effect. For example, inward movement of the plunger decreases the inductance *L* of the cavity but increases the capacitance *C*. By utilizing the novel capacitive shield 29, *C* remains substantially constant throughout the tuning range of the cavity such that only *L* is a function of the plunger travel. It has been found that this novel combination yields a linear frequency versus plunger travel characteristic. The linear tuning characteristic makes this tuner ideally suited for use in gang tuners.

The electrical effect of the tuning plunger 28 is to perturb the electromagnetic field configuration within the cavity resonator generally as shown in FIGS. 6 and 6A. When the tuning plunger 28 is fully retracted, as shown in FIG. 6, the amount of magnetic field displacement is a minimum. FIG. 6A shows how the magnetic field is displaced when the tuning plunger 28 is fully extended. Accompanying the magnetic field displacement is a shift in the strong axial electric field of the resonator to a point off of its axial center line. This means that the electric field in the gap region will be weaker on the side adjacent the tuning plunger.

It is desirable that substantially the same amount of work be done on an electron or received from an electron irrespective of its radial position in the beam. The work done on an electron as it traverses the gap can be found approximately from the relationship $V = \int \vec{E} \cdot d\vec{s}$, where *V* is the work done, $\vec{E}$ is the electric field strength, $d\vec{s}$ is an increment of the electron path over which work is being done, and the $\int$ is the line integral over the electron path. From the above relationship it can be seen that if *E* is weaker near the tuning plunger then, in order for the work *V* to remain the same, *ds* must be increased nearer the plunger. Accordingly it will be seen that the gap spacing (integral of *ds*) has been increased near the tuning plunger by skewing the end of the drift tube 12.

Hollow tuner actuating rods 38 are secured at one of their ends to the outer ends of actuating arms 36 of the respective tuner assemblies, these rods 38 extending longitudinally of the tube apparatus through a plurality of non-contacting apertures in the flange-like flat cavity end walls 31 and a collector pole piece 39. The four actuating rods 38 are spaced-apart around the klystron for adequate clearance. A septum 41 is longitudinally disposed in each of the hollow tuner actuating rods 38 and serves to divide the rod into two communicating chambers. The septum 41 is spaced apart from the end of the tuning rod whereby coolant fluid may circulate through the actuating rod thus minimizing thermal expansion and contraction of the actuating mechanism which would be transmitted to the tuning plunger. Cylindrical actuating rod extensions 42 (FIG. 1) are secured to the ends of the actuating rods 38. A right angular tuner support bracket 43 is mounted on the collector assembly 2. The tuner actuating rod extensions 42 protrude through annular bearings 43' in the tuner support bracket 43.

A windlass axle 44 is mounted in bearings 44' transversely to the longitudinal axis of the tuning actuating rods 38 (see FIGS. 1 and 7). A plurality of semi-cylindrical windlass drums 45 are fixedly mounted on the windlass axle 44, separate ones being associated with separate ones of the actuating rods. Channeled windlass adjustment members 46 (FIG. 1) are pivotally mounted in straddling fashion over a flat chord portion of each windlass drum. A protrusion 46' of each adjustment member engages an opening in the end of associated band adaptors 47. Band adjustment screws 48 are threaded through the adjustment members 46 and their extremities bear upon an indented portion of the flat side of the associated windlass drum 45. Metallic tuning bands 49 are fixedly secured at one end to the band adaptors 47 and are threaded over the curved portion of the associated windlass drums 45. The bands are further threaded over rollers 51 with their other ends secured to a second group of band adaptors 52 which in turn are secured to threaded tuner plugs 53. The threaded tuner plugs 53

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screw into threaded holes in one end of the associated tuner actuating rod extensions 42. Locknuts 54 screw over the tuner plugs 53 and lock against the end of the actuating rod extensions 42.

A worm gear 55 is fixedly mounted on the windlass axle 44 and cooperates with a tangentially positioned worm shaft 56 to produce rotation of the windlass drums 45.

In tuning of the cavities, except the output cavity 11, the tuner actuating mechanism operates as follows (see FIGS. 5 and 1): Atmospheric pressure serves to provide a force tending to push the tuning plunger 28 into the cavity resonator. Restraining this force is the tension in the tuning band 49 which is secured to the windlass drum 45. Rotational motion of the worm gear 55 through the intermediary of the worm shaft 56 serves to turn the windlass drum 45 either permitting the tuning band 49 to be drawn by the atmospheric caused force or winding in the tuning band against the atmospheric caused forces.

Referring now to FIG. 1 it can be seen that the input cavity 7 and intermediate bunching cavities 8 and 9 are mounted with their domed portions facing the cathode assembly 1. However, the output cavity resonator 11 has been reversed such that its tuning plunger 28 enters the cavity from the cathode end of the tube (FIG. 9). This arrangement reduces the over-all length of the tube apparatus by approximately the length of a tuning plunger assembly.

Reversion of the output cavity position with respect to the other cavities introduces the complication of having its tuner plunger 28 move in the opposite direction to the other plungers to produce the same sense of tuning. In order to obviate this reversed motion requirement the output cavity windlass drum 57 was reversed (FIGS. 7 and 8). The tuning band 49 was threaded under instead of over the drum and thence over the roller 51.

In tuning of the reversed output cavity 11 the tuner actuating mechanism is constructed as follows (see FIGS. 7, 8 and 9): A compression spring 58 is mounted surrounding the actuating rod extension 42' and bears at its lower extremity upon a collar 59 fixedly mounted on the actuating rod extension 42'. An apertured header 61 is slideably mounted on the actuating rod extension 42 and bears upon the other end of the spring 58. An L-shaped cam lever 62 is pivotally mounted on a pedestal 63. One end of the cam lever 62 is forked and bears upon the outward surface of the header 61 thereby determining the spring pressure and thus the force exerted on the tuner actuating rod, said force being counter to the atmospheric force. A cam roller 64 is mounted on the other extremity of the cam lever 62. An eccentric cam 65 is axially mounted on the windlass axle 44 adjacent the output cavity windlass drum 57. The cam roller rides on the periphery of the cam 65.

In operation of the output cavity tuner the spring tension is determined by the position of the lever 62. The initial positioning of the cam lever 62 and spring 58 is set such that the spring force just over-balances the atmospheric force thereby taking up the slack in the tuner band 49 and putting some small torsion forces on the output windlass drum 45. When the windlass is rotated in a counterclockwise direction, the cam roller 64 rides over the raised portion of the cam 65 and depresses cam lever 62. Depressing the cam lever 62 puts additional spring force on the tuner actuating rod 38 which then takes up the slack produced in the tuner band 49. Rotation of the output windlass drum 57 in the clockwise direction causes the spring force to decrease thereby making it easier for the windlass to wind in the tuner band 49 against the spring force.

In gang tuning of the tube, rotation of worm shaft 56 imparts rotation to the windlass axle 44 through the intermediary of worm gear 55. Adjustment of the individual tuning plungers within the resonators is provided by the adjusting screws 48. For example, referring now to FIG.

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10 the hypothetical frequency versus tuner position characteristics for cavities 7, 8 and 9 are depicted. Cavity 8's characteristic may be moved over to coincide with the characteristic of cavity number 7 by making an adjustment with adjusting screw 48 thereby adjusting the initial positioning of the tuning plunger.

On the other hand if the tuning rate differs as is shown by curves 7 and 9 the previously mentioned adjustment will make the origins of curves 7 and 9 coincide but to obtain the same tuning rate (slope) the diameter of cavity number 9's windlass may be increased.

Thus in summary the present novel tuner assembly, firstly, provides a satisfactory linear tuning characteristic. Secondly, it provides means for adjusting the tuning rates of the individual cavities as desired.

A plurality of hollow metallic stringers 67 (FIGS. 1 and 4) as of, for example, non-magnetic stainless steel extend the length of the R.F. section to assure rigidity of the tube apparatus. Moreover, certain of the stringers 67 convey coolant to the flared initial portion of the drift tube 12 to prevent overheating. The stringers interconnect the flange-like flat end walls 31 of the cavity resonators and are terminated in the cathode pole piece 25 and collector pole piece 39.

A thin metallic housing 68 covers the windlass mechanism. A hollow cylindrical lead shield 69 surrounds the collector assembly and serves as a shield for dangerous X-ray radiation emanating from the collector in use.

In operation electrons are emitted from the cathode 5, focused into the beam by the focusing electrode 66 and accelerated through the first drift tube 12. The signal to be amplified is fed into the input cavity 7 over coaxial line 13 where the beam is velocity modulated. As the modulated beam travels down the drift tubes 12 it is further modulated by the intermediate bunching cavities 8 and 9. While within the drift tube the beam is confined in diameter against forces tending to spread the beam, such as space charge forces, by the magnetic field lines supplied by the focusing solenoid 4, said lines of flux being parallel to the drift tube in this region. The output cavity extracts electromagnetic energy from the modulated beam and said energy is then coupled out of the output cavity through iris 15 and propagated through waveguide 16 and window 18 to the load.

Tuning of the tube is accomplished by the shielded tuning plungers 28 and associated tuning apparatus as described above. As above stated, rotation of the singular worm shaft will simultaneously tune all of the cavity resonators of the novel electron tube apparatus.

Since 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. In an electron tube apparatus employing a plurality of cavity resonators arranged for successive electromagnetic interaction with a pencil-like beam of electrons, a plurality of tuning plungers movable within the electromagnetic fields of the cavity resonators, a plurality of tuner actuating rods coupled to said plungers and extending longitudinally of the tube apparatus, a windlass means disposed at one end of said actuator rods for moving said rods longitudinally of the tube apparatus through the intermediary of a plurality of flexible bands, and gear means driving said windlass whereby the transverse dimension of the tube apparatus is minimized to facilitate beam confining.

2. An apparatus as claimed in claim 1 wherein a flat portion is provided on said windlass means, and a windlass adjustment means is pivotably mounted over said flat portion whereby adjustments may be made in the individual position of the tuning plungers.

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3. An apparatus as claimed in claim 1 wherein said actuator rods include an internal partition whereby coolant may be circulated through said rods thereby minimizing thermal contractions and expansions in use.

4. In an apparatus as claimed in claim 1, a vacuum-tight flexible wall means disposed surrounding said tuning plungers and coupled to said tuning plungers in a vacuum-tight manner whereby the said tuning plungers are allowed to move without destroying the vacuum integrity within the cavity resonators.

5. In an electron tube apparatus having a plurality of cavity resonators arranged for successive electromagnetic interaction with the beam of electrons passable therethrough and having a cathode assembly including, a cathode emitter connected to and contained within a tubular cathode envelope, said tubular envelope abutting at one end thereof against an annular transverse header for longitudinal alignment of said cathode emitter, a first ring member carried externally of and substantially at the abutting end of said cathode envelope, a second ring member for mating with said first ring member and being concentrically disposed of said first ring member and fixedly connected to said annular transverse header for transversely aligning said cathode emitter with respect to the tube apparatus, and means for sealing the mating portions of said first and said second ring members in a vacuum tight manner.

6. The apparatus as claimed in claim 1 wherein said windlass includes means for moving certain ones of said tuning plungers at different rates such that the cavity resonators may be simultaneously tuned at certain predetermined rates.

7. In an electron tube apparatus applying a plurality of cavity resonators arranged for successive electromagnetic interaction with a pencil-like beam of electrons, a plurality of tuning plungers movable within the electromagnetic fields of the cavity resonators, a plurality of tuner actuating rods coupled to said plungers and extending longitudinally of the tube apparatus, a windlass means disposed at one end of said actuator rods for moving said rods longitudinally of the tube apparatus through the intermediary of a plurality of flexible bands, and gear means driving said windlass whereby the transverse dimension of the tube apparatus is minimized to facilitate beam confining, whereby said plungers are provided with longitudinal bores therein, and guide means extending longitudinally of and operating within the bores whereby the rectilinear motion of the tuning plungers is precisely controlled.

8. The apparatus according to claim 7 including spring means coupled to said tuner actuator rod, said spring means formed and arranged to urge said plungers out of the electromagnetic fields of the resonators, cam means mounted adjacent said windlass means, cam level means co-operating with said cam means to increase the spring force on said actuator rods when said plungers move outwardly of the electromagnetic fields of the resonators.

9. In an electron tube apparatus employing a plurality of cavity resonators arranged for successive electromagnetic interaction with a pencil-like beam of electrons, a plurality of tuning plungers movable within the electromagnetic fields of the cavity resonators, a plurality of tuner actuating rods coupled to said plungers and extending longitudinally of the tube apparatus, a windlass means disposed at one end of said actuator rods for moving said rods longitudinally of the tube apparatus through the intermediary of a plurality of flexible bands and a plurality of windlass drum means fixed to said windlass means, said windlass drum means including band adjustment means for moving certain ones of said tuning plungers at different rates such that the cavity may be tuned at certain predetermined rates, and gear means driving said windlass whereby the transverse dimension of the tube apparatus is minimized to facilitate beam confining.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,132,280

May 5, 1964

Robert C. Schmidt

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 32, for "ceramic-to-cut" read -- ceramic-to-cup --; column 8, line 45, for "whereby" read -- wherein --.

Signed and sealed this 2nd day of March 1965.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents