Sept. 18, 1962 R. L. WALTER ET AL 3,054,925

HIGH POWER KLYSTRON TUBE APPARATUS

Filed Jan. 15, 1959

4 Sheets-Sheet 1

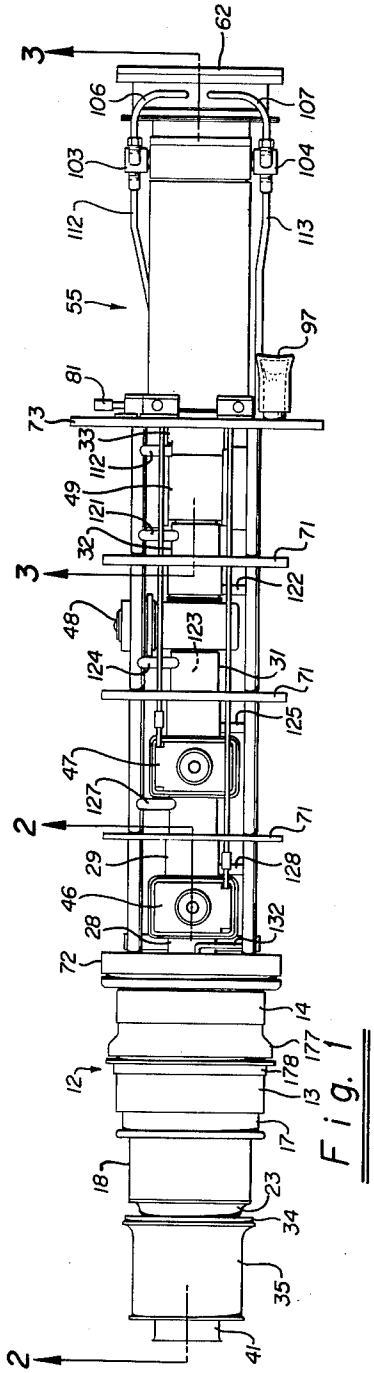


Fig. 1

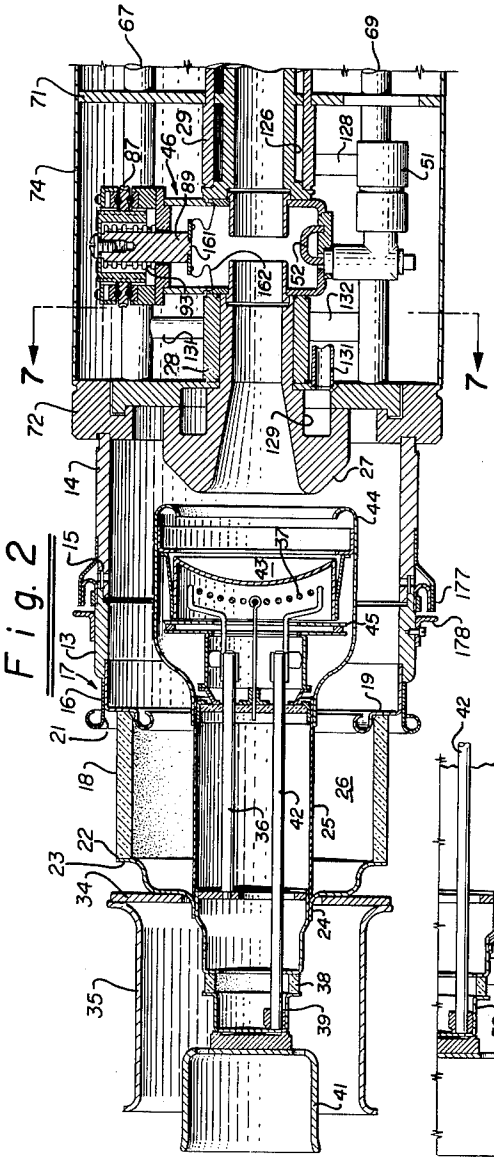


Fig. 2

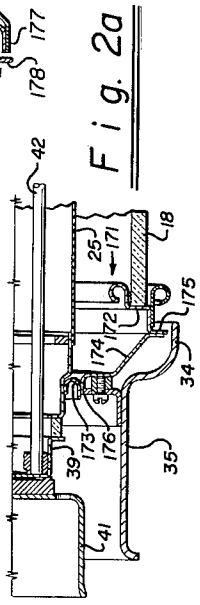


Fig. 2a

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4 Sheets-Sheet 2

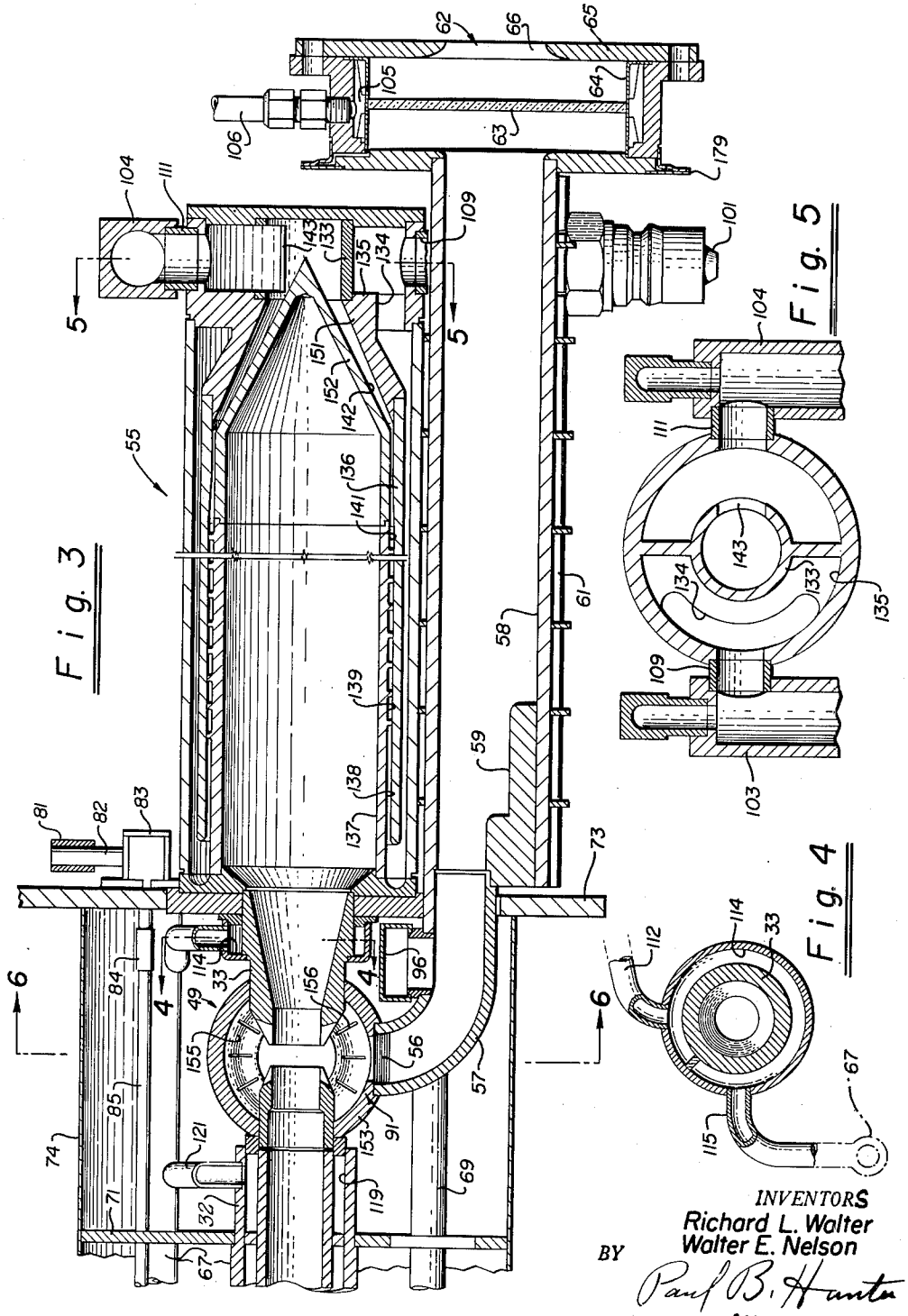


Fig. 3

Fig. 5

Fig. 4

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HIGH POWER KLYSTRON TUBE APPARATUS

Filed Jan. 15, 1959 4 Sheets-Sheet 3

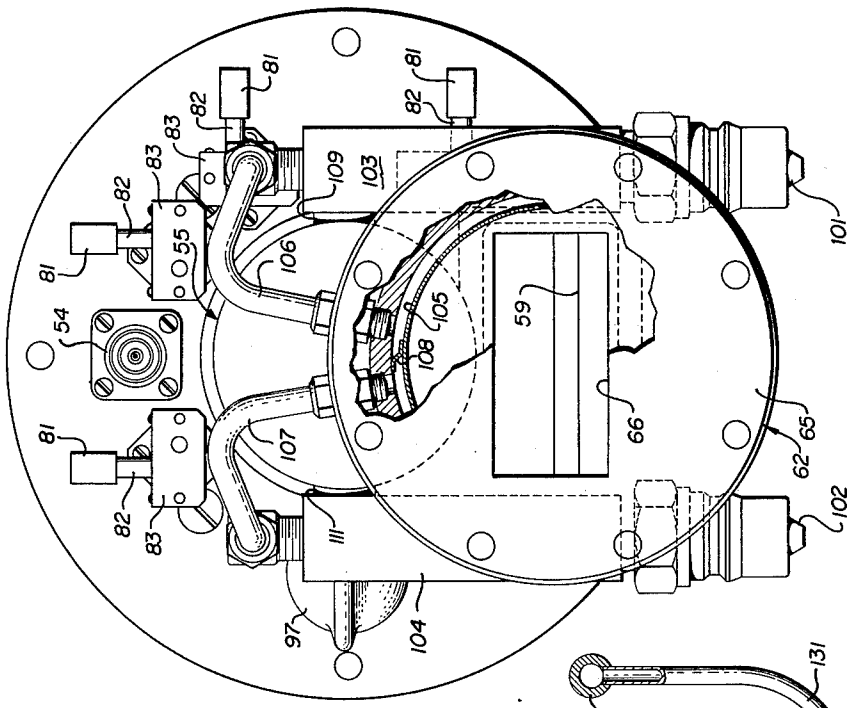


Fig. 8

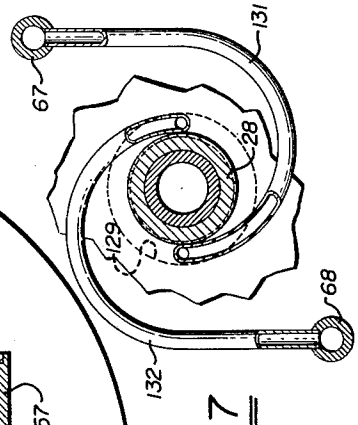


Fig. 7

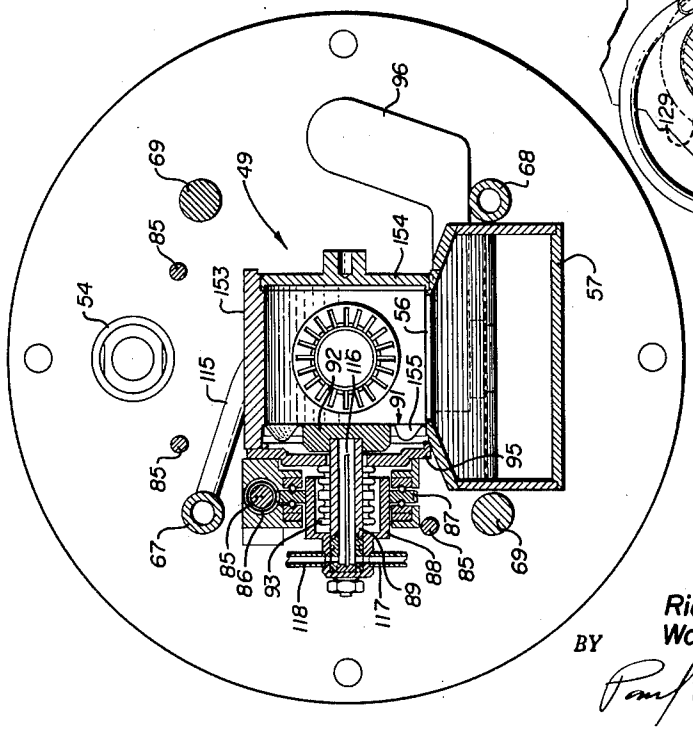


Fig. 6

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HIGH POWER KLYSTRON TUBE APPARATUS

Filed Jan. 15, 1959 4 Sheets-Sheet 4

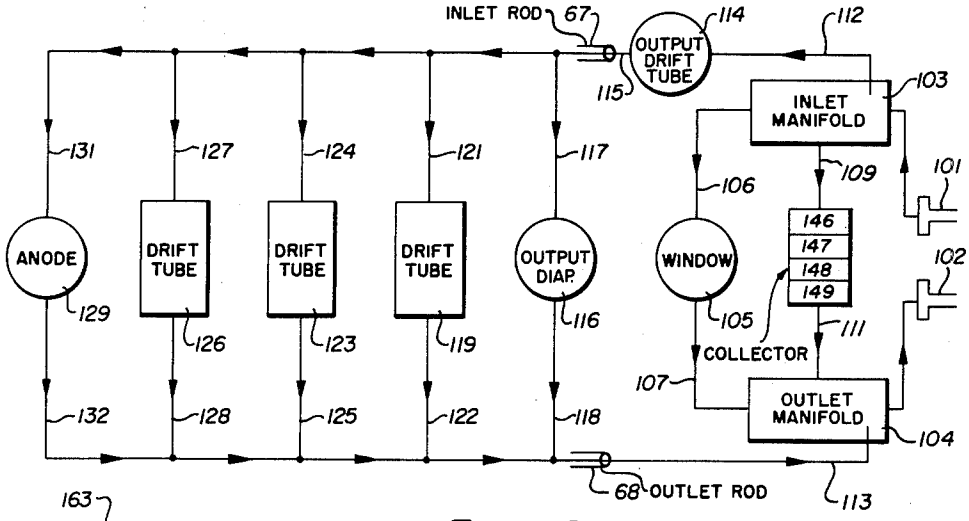


Fig. 9

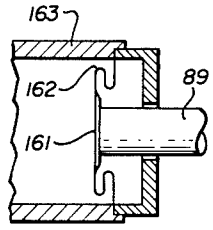


Fig. 10a

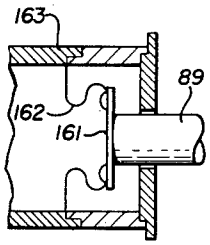


Fig. 10b

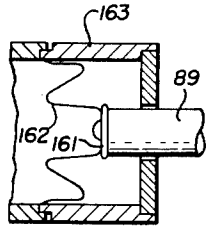
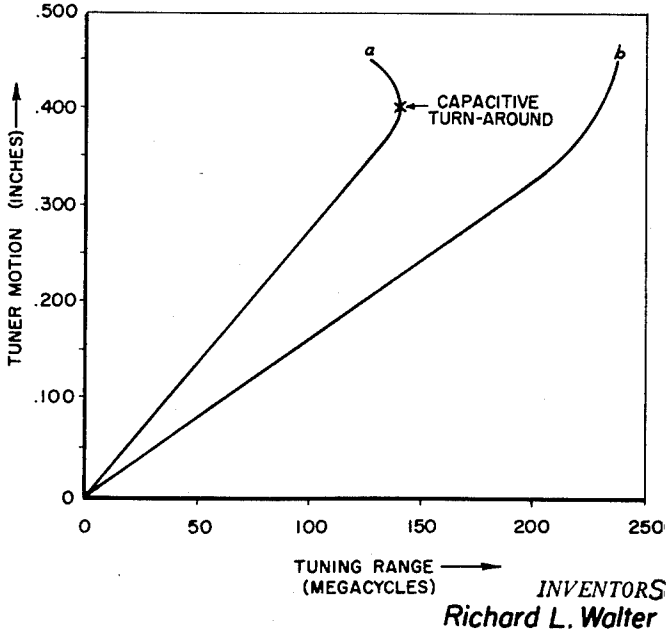


Fig. 10c

Fig. 11



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HIGH POWER KLYSTRON TUBE APPARATUS

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Filed Jan. 15, 1959, Ser. No. 787,082
25 Claims. (Cl. 315—5.48)

This invention relates in general to tube apparatus and in particular to novel electron tube apparatus of the type employing cavity resonators, such as high power klystron tubes useful, for example, as power amplifiers in transmitter systems and as power sources for linear accelerators.

In such applications it is often necessary to produce pulses of high frequency electromagnetic energy in the range of about 1700 to 5000 megacycles with a peak power of at least 2 to 5 megawatts. Further it is desirable that such a pulsed amplifier klystron produce an output which is high in average power, that is, power averaged over both the pulse and between-pulse portions of the operating cycle, thus permitting pulses of longer duration for a given peak power and pulse repetition rate.

Heretofore no tube has been available capable of satisfactory operation consistent with the above power requirements. For example, attempts to increase the average power output of prior art tubes beyond a few kilowatts have resulted in such failures as the cracking of the output waveguide window due to overheating and the melting of the output cavity tuning diaphragm due to high cavity circulating currents.

Accordingly, it is the object of this invention to provide a novel, high efficiency, high gain klystron tube apparatus capable of reliable operation over a wide band of frequencies at both high peak power and high average power output levels.

One feature of the present invention is the provision of a novel cooling system enabling long, reliable tube operation at high power levels by providing efficient transfer of excessive heat generated in certain tube components.

A second feature of the present invention is the provision of a novel collector cooling channel structure, the heat transfer characteristics of which are effectively matched to the power density distribution of incident electrons over the electron beam collecting surface thereby permitting efficient beam energy cooling at a minimum of fluid pressure.

A third feature of the present invention is the provision of a novel resonant cavity and flexible tuning diaphragm structure enabling efficient removal of heat due to high power cavity circulating currents and permitting diaphragm movement with a minimum of mechanical stress.

A fourth feature of the present invention is the provision of a novel alignment joint structure which permits precise electron gun to anode alignment thus minimizing beam power losses.

A fifth feature of the present invention is the provision of a novel corona shield structure for facilitating the making and protection of high voltage metal-to-insulator seals.

A sixth feature of the present invention is the provision of a novel tuning diaphragm for greatly increasing the available tuning range of an inductive type tuner.

These and other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein the same numerals are used in the various figures to designate the same or analogous elements and wherein,

FIG. 1 is a plan view showing the general construction of a novel high power klystron tube in accordance with the present invention with the protective cover removed,

FIG. 2 is an enlarged cross-sectional view of a portion of the structure of FIG. 1 taken along line 2—2,

FIG. 2*a* is a modification of the structure shown in FIG. 2 embodying the novel corona shield and electron gun alignment structures of the present invention,

FIG. 3 is an enlarged cross-sectional view of a portion of the structure of FIG. 1 taken along line 3—3, a portion of which is broken away and rotated 90° to show the collector cooling fluid distribution structure,

FIG. 4 is a fragmentary view taken along line 4—4 of FIG. 3 showing the output drift tube cooling channel,

FIG. 5 is a cross-sectional view of a portion of the structure of FIG. 3 taken along line 5—5 showing the fluid distributor for the collector cooling channel structure,

FIG. 6 is a view taken along line 6—6 of FIG. 3 showing the output cavity structure of the present invention,

FIG. 7 is a view taken along line 7—7 of FIG. 2 showing the anode cooling structure,

FIG. 8 is a right end view, partially broken away, of the tube structure shown in FIG. 1,

FIG. 9 is a schematic diagram of the cooling fluid flow circuits of the present invention,

FIG. 10*a* is a cross-sectional view of a known type of inductive cavity tuner,

FIG. 10*b* is a cross-sectional view of an inductive cavity tuner in accordance with the present invention,

FIG. 10*c* is a modification of the tuner shown in FIG. 10*b*, and

FIG. 11 is a plot of the tuning curves for the tuners of FIGS. 10*a* and 10*b*.

Referring now to the drawings, a segmented tubular cathode assembly 12 provides a beam of electrons which are projected longitudinally within the tube apparatus. The cathode assembly 12 includes a metallic cathode socket 13 which is adapted for take-apart connection to anode adapter 14 at joint 15. Integrally attached (as by brazing) to the cathode socket is one arm 16 of a T-shaped cross-section corona shield termination 17 as of, for example, Kovar. An insulating cylinder 18 as of, for example, ceramic is vacuum sealed to corona shield termination 17 at leg 19 thereof. Leg 19 and arm 21 each terminate in a rounded corona scroll, thus protecting the vacuum seal by eliminating high voltage gradients and electron bombardment punctures thereat. The other end of the cylinder 18 is vacuum sealed at 22 to a conducting seal ring 23. This vacuum seal may also be protected by a corona second shield, such as 171 in FIG. 2*a*, but satisfactory results are obtained by using a single corona shield as shown in FIG. 2. Ring 23, in turn, is vacuum sealed at 24 to the housing 25 of electron gun subassembly 26, longitudinally aligning the electron gun with respect to anode 27 and drift tubes 28, 29, 31, 32 and 33.

Transversely secured to ring 23 is an annular cathode flange 34 serving to strengthen the fragile cathode envelope and providing bumper protection for insulator 18. Extending from flange 34 is a tubular cathode socket 35 adapted to receive a high negative beam pulsing voltage (anode 27 being preferably at ground potential) applied via flange 34 and ring 23 to the electron gun housing 25 and via lead 36 to one side of heater filament 37.

Extending rearward of electron gun housing 25 are a heater voltage insulating member 38, a metallic cup 39 and a heater socket 41, heater socket 41 being adapted to receive a heater voltage applied via lead 42 to the other end of filament heater 37. Heated by filament 37 is a concave focusing cathode emitter button 43. Supported adjacent electron emitter 43 are an electron focusing ring 44 and a double partition heat shield 45 for increasing the thermal efficiency of the cathode.

Spaced along the electron beam path are a plurality of cavity resonators 46, 47, 48 and 49, each of which is centrally apertured to form an interaction gap between

adjacent drift tube segments 28, 29, 31, 32 and 33. Input resonator 46 and buncher cavities 47 and 48 are preferably of rectangular box-type configuration whereas output cavity 49 is preferably cylindrical. Details of the construction of the cavity resonators will be described subsequently.

Electromagnetic energy, which it is desired to amplify, is fed to the input cavity 46 by means of a vacuum sealed coaxial connector 51 and coupler loop 52. Connector 51, in turn, is adapted for external connection through a coaxial line (not shown) and an externally mounted panel jack 54 (FIG. 8).

The electron beam passes from output cavity 49 through output drift tube segment 33 and terminates in the electron collecting structure 55, the details of which will be described subsequently.

The output energy is propagated from output cavity 49 through iris 56 and transition member 57 along a waveguide 58 which is provided with an impedance matching baffle 59 and a plurality of stainless steel stiffening members 61 which guard against wave guide buckling due to pressure differentials experienced upon exhaustion of the tube. The output energy passes from waveguide section 58 to a circular window waveguide structure 62 having midway therein a gas-tight wave permeable window 63 as of, for example, aluminum oxide which is sealed in a vacuum tight manner to a thin metallic ring 64 as of, for example, copper thus allowing for the thermal expansion and contraction of window 63 and ring 64 without breaking the seal between these members. In order to provide transmission over a wide band of frequencies, it is found preferable to make the circular waveguide window structure electrically in the order of one-half wavelength at the center frequency of the pass band. The window structure 62 is terminated by a flange 65 adapted to accommodate an external waveguide into which energy is coupled through an iris 66.

Proper alignment and rigidity of the apparatus under adverse shock, vibration and temperature conditions are maintained by hollow stiffener tubes 67 and 68, stiffener rods 69 and stiffener plates 71 thereby reducing the microphonic tendency of the tube and enhancing the electrical stability under high ambient temperatures.

The stiffener rods and tubes terminate in magnetic pole pieces 72 and 73 which are adapted to accommodate an external magnet structure (not shown) in which the tube is mounted. The external magnet provides a flux path bounded by pole pieces 72 and 73 giving rise to a magnetic field for focusing the electron beam as it passes from the cathode through the various cavities and drift tubes to the collector. This section of the tube is preferably enclosed by a protective cover 74 as of, for example, aluminum. Pole pieces 72 and 73 are constructed of a material of high magnetic permeability such as, for example, iron. On the other hand, in the area between the pole pieces the magnetic field should not be perturbed, and thus, where possible, parts should be made of materials possessing no magnetism. For example, the stiffener rods 69, tubes 67, 68 and plates 71 could be constructed of a non-magnetic variety of stainless steel.

A plurality of tuner shaft couplers 81 are mounted on pole piece 73 to permit tuning of the cavity resonators from a remote station, safe from the hazards of X-radiation. As best seen in FIGURE 3, the rotation of each coupler shaft 82 is transformed via a helical gear assembly 83 and tuner shaft coupler 84 into rotation of a tuner shaft 85. As shown in FIGURE 6, each tuner shaft 85 terminates in a worm gear 86 at one of the cavity tuner assemblies. The rotation of warm gear 86 is transformed, via ring gear 87 and tuner cap 88 captured for translation therethrough, into the tuning motion of a tuning piston 89 and a tuning diaphragm, such as 91, attached thereto as at tuner plug 92. A bellows 93 is sealed to piston 89 and cavity cover 95 in order to maintain the vacuum provided by exhausting the tube through exhaust pipe 96 and sealing the end thereof at pinch-off point 97.

Fluid cooling of the tube is provided through fluid fittings 101 and 102 which lead, respectively, to inlet manifold 103 and outlet manifold 104 mounted on opposite sides of the electron collector 55 as shown in FIGURE 8. With the aid of fluid flow circuit diagram of FIGURE 9, it is seen that the fluid flowing between the inlet and outlet manifolds divides into three parallel flow paths. One of these paths circulates through window cooling channel 105 via conduits 106 and 107 separated by baffle 108 (FIG. 8). The second of these parallel flow paths circulates cooling fluid through the electron collecting structure 55 via manifold adaptors 109 and 111. The third parallel flow path circulates to the remainder of the tube components via conduits 112 and 113 and hollow stiffener tubes 67 and 68. The fluid flowing from inlet manifold 103 via conduit 112 passes in series through output drift tube cooling channel 114 and conduit 115 into inlet tube 67 and then divides into five parallel branches flowing back through the outlet tube 68 and conduit 113 into outlet manifold 104. The first parallel branch flows through output diaphragm channel 116 via conduits 117 and 118. The second parallel branch flows through drift tube cooling channel 119 via conduits 121 and 122. The third parallel branch flows through drift tube cooling channel 123 via conduits 124 and 125. The fourth parallel branch flows through drift tube cooling channel 126 via conduits 127 and 128. And the fifth parallel branch flows through anode cooling channel 129 via conduits 131 and 132.

The details of the collector cooling channel are shown in FIGURES 3 and 5. Fluid flows in from inlet manifold 103 through manifold adapter 109 and is forced by fluid deflector 133 through a curved opening 134 in fluid distributor 135 and along baffle 136. The fluid then reverses direction and flows adjacent electron collecting surface 137 through cylindrical cooling channel 138, helical cooling channel 139, a second cylindrical cooling channel 141 and a conical cooling channel 142. The fluid is then forced by the cylindrical interior of deflector 133 through a slot 143 therein and thence into outlet manifold 104 via manifold adapter 111.

In veiw of the relatively large amount of energy dissipated in the electron collector, it is found desirable to use a helical cooling channel such as 139 since this structure passes the fluid at a high velocity and provides good heat transfer contact with the metallic electron collecting surface 137. However, such a cooling channel has the disadvantage of presenting a high impedance to the flow of fluid therethrough and thus requires a large amount of pressure to obtain the desired rate of flow. In accordance with the present invention, it is sought to lessen the required pressure by combining the helical cooling channel with other cooling channel configurations presenting less fluid impedance. This is accomplished by providing a helical structure adjacent only that portion of the electron collecting surface at which the power density distribution of incident electrons is at a maximum and in using cooling channel structures of other configurations presenting less fluid flow impedance but having inferior heat transfer characteristics adjacent those portions of the electron collecting surface where the incident electron power distribution is accordingly less. Thus pressure is conserved when the electron cooling channel structure, taken as a whole, is effectively matched to the power density distribution of electrons over the entire electron collecting surface.

A region of maximum electron power density can be conveniently determined by considering the ideal case of a uniform parallel electron beam entering a field free collector space. It can be shown that the spread of such

a beam under space charge forces results in electrons following paths described by the equation:

$$Z=2\int_0^{(\ln R)^{1/2}} e^{u^2}du$$

where

$R=r/r_0$(r=radius of electron paths which entered at radius r_0),

$$Z=174I^{1/2}/V^{3/4}\frac{z}{r_0}$$

z=axial distance from source
I=current inside radius r_0, and
V=beam voltage

From this equation a curve representing the envelope of electron paths, known as a universal beam spread curve, can be determined. The intersection of this universal beam spread curve with the electron collecting surface thus determines a region of maximum power density distribution. As is seen in FIGURE 3, the electron energy dissipation outside the above defined region is effectively matched by a first cylindrical channel **138**, a second cylindrical channel **141** of diminishing thickness, and a conical cooling channel **142**. It has been determined that the best heat transfer match in channel **142** is obtained when the apex of the truncated conical surface **151** (extended) of fluid distributor **135** is rearward of the apex of the conical end portion **152** of the electron collecting surface **137** and when the first named apex is slightly less in angular measure than the second named apex.

The collector of the present invention is not limited to electron tubes, but may be used in any application requiring the interception of a high energy beam of charged particles, including, for example, positive ions.

Referring to FIGURE 9 the above obtained advantage of low optimum pressure drop across the collector cooling channel is preserved by placing that channel in fluid flow parallel with the other cooling channels. The fluid flow impedances of the remaining cooling circuits can then be designed for operation at this optimum pressure and yet provide a sufficient rate of fluid flow for the cooling requirements of the remaining tube components. It is to be further noted that all of the cooling fluid circulating to components forward of output drift tube **33** circulates through drift tube cooling channel **114**, since the cooling requirements of this component are more severe.

Referring now to the output cavity structure **49** as best shown in FIGURES 3 and 6, a cylindrical cavity wall **153** as of, for example, copper is enclosed by a flange **154** and a tuning diaphragm **91** of a thin, flexible material such as copper-plated stainless steel. Diaphragm **91** is adapted for back and forth translation by heat conducting attachment (as by brazing) to tuner plug **92** of a good heat conducting material, such as copper, said tuner plug, in turn, being cooled by fluid circulation through channel **116** formed in the partitioned interior of piston **89**. The bendable portion **155** of the output diaphragm is likewise secured in good heat conducting relation to cavity wall **153**. In order to relieve excessive circumferential stresses in the bending portion **155**, a plurality of generally radial slots **156** are cut through the diaphragm (the diaphragm having been rotated 90° in the drawing for the sake of clarity). These slots are also substantially parallel to the direction of current flow necessary to support the cavity resonant mode so as not to interfere therewith. It is thus seen that excessive heat due to high circulating currents in the diaphragm are rapidly conducted away by good thermal connection of the tuning diaphragm to heat conducting members **92** and **153** thus allowing high power operation of the tube without the danger of melting the thin diaphragm **91**. In addition to relieving stresses, slots **156** permit the exhaustion of the space between cavity cover **95** and diaphragm **91** thus preventing air pockets and resulting pressure differentials from acting on the thin diaphragm surface.

Referring to FIGURE 10*a* there is shown a known type of inductive tuner for a cavity resonator. A thin tuning diaphragm comprising a translation surface **161** and a bending surface **162** is secured to the cavity wall **163** at a position exterior of translation surface **161** when piston **89** is in a fully withdrawn position. As the piston is moved inward, the resonant frequency of the cavity resonator defined by the cavity wall and drift tube interaction gap therewithin, under typical operating conditions, changes in accordance with tuning curve *a* in FIGURE 11. It is to be noted that this tuner in effect changes at point *x* from inductive tuning to capacitance tuning. This is apparently due to the fact that as the translation surface **161** approaches the vicinity of the drift tube interaction gap the capacitance of the cavity starts increasing faster than the inductance of the cavity is decreasing. This capacitance turn around severely limits the effective tuning range since further inward movement of the tuning piston beyond point *x* will not further increase the resonant frequency.

By reversing the convolutions of the doubly-flexed bending surface **162** and securing the ends thereof interior of the translation surface **161**, as shown in FIGURE 10*b* and in accordance with the preferred embodiment of the present invention (see cavity **46** in FIGURE 2), it is possible to eliminate the above-mentioned capacitive turn around and also to increase the tuning rate (megacycles/inch) due to the larger volume displacement in the region of high intensity magnetic fields. As is seen by inspection of tuning curve *b* in FIGURE 11, the tuner of the present invention, under typical operating conditions, enables an increase of greater than 50% in tuning range. Thus, the tube of the present invention has a heretofore unobtainable flexibility of operation over a wide range of frequencies.

As a further illustration of the advantages of the novel tuner of the present invention, it is often desirable to amplify over a broad band of frequencies without any mechanical adjustment of the tuner mechanism. This may be done by stagger-tuning; that is, by tuning each of the cavity resonators to a different frequency, said frequencies being distributed over a band which is at least partially coextensive with the desired pass band without the inflexible requirement of permanent differences in dimensions from cavity to cavity.

The modification of the tuner of the present invention shown in FIGURE 10*c*, incorporating longer bending convolutions, operates under less severe bending stresses, thus assuring longer life although at somewhat of a decrease in effective tuning range.

A modification of the cathode assembly structure of FIGURE 2, shown in FIGURE 2*a*, permits extremely precise alignment of the electron gun emitting surface **43** with respect to the anode **27** and drift tubes **28**, **29**, **31**, **32** and **33** thus minimizing beam power losses due to interception of the electron beam. In accordance with this feature of the invention, the cathode housing is first assembled in the following manner. The cylindrical anode adapter **14** is fixedly secured to pole piece **72** as by brazing; cathode socket **13** with corona shield **17** integrally secured thereto is temporarily sealed to adapter **14** at take-apart joint **15**; insulator **18** is vacuum sealed as by brazing to the leg **19** of corona shield **17**; and finally a second T-shaped corona shield **171** (FIGURE 2*a*) is likewise vacuum sealed to insulator **18** at leg **172** thereof.

The electron gun subassembly **26** having a flexible U-shaped member **173** as of, for example, nickel secured to housing **25** thereof as by brazing is then inserted into the cathode housing and is temporarily secured at a desired distance from anode **27** and in proper alignment therewith using, for example, an aligning mandrel (not shown) inserted into anode **27**. The desired transverse alignment is then secured by abutting the transversely extending

surfaces of corona shield 171 and a transition piece 174 and sealing the transverse translation joint 175 thus formed by a heliarc weld at the extremity thereof. It is to be noted that the position of the members of joint 175 compensates for transverse misalignment in the electron gun subassembly between the temporarily aligned emitting surface 43 and the permanent supporting area at the attachment of flexible member 173. Next the flexible member 173 is slightly bent (if necessary) to abut the longitudinally extending surface of transition piece 174 thus compensating for axial misalignments in the electron gun subassembly. The longitudinal translation joint 176 thus formed is then sealed at the extremity thereof by a heliarc weld to maintain the desired longitudinal spacing of electron gun 26 from anode 27. The cathode housing, with the electron gun subassembly fixedly secured therein, is now withdrawn by breaking the temporary seal at joint 15 thus allowing removal of the temporary aligning structure. The cathode assembly is then resealed at joint 15 and a vacuum seal is made by a heliarc weld at the extremity of joint 177 defined by a pair of longitudinally abutting rings secured to the opposite members of joint 15. This vacuum seal is protected by a heavy bumper guard flange 178. The use of the aforementioned heliarc welds facilitates the removal and replacement of the electron gun; it is only necessary to file down the extreme ends of joints 177, 176, and 175 a short distance to remove the weld and replacement is made by re-welding at the new extremities of the joints. Replacement of window structure 62 is likewise facilitated by a heliarc weld at the extremity of joint 179 (FIGURE 3).

In operation, the electron gun 26 is sequentially energized, as desired, to provide a pulsed beam of electrons. As the beam passes through cavity 46, it is velocity modulated therein by the electromagnetic energy input 52. The velocity modulation of the beam is then transformed into current density modulation in the drift tube spaces between the input cavity 46 and the first buncher cavity 47. Buncher resonators 47 and 48 further velocity modulate the beam to produce greater current density modulation of the beam at the output cavity 49 inducing therein greatly amplified electromagnetic energy. Finally, the electromagnetic energy output is propagated from output cavity 49 through window 62 to an external load.

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. A high power klystron tube apparatus including: an electron gun for producing a beam of electrons; a permeable anode adapted to accelerate said beam along a desired axis; a plurality of tunable cavity resonators spaced along said axis and adapted for electromagnetic interaction with said beam, all but the last of said cavity resonators being closed by a flexible tuning diaphragm having a translation surface portion and a bending surface portion, said bending surface being secured to the walls of said cavity resonator inwardly of said translation surface; a plurality of drift tubes adjoining adjacent cavity resonators and providing an electromagnetic interaction gap therein, the last of said cavity resonators having a slotted tuning diaphragm in good heat conduction relation with the wall of said last cavity resonator; an output drift tube leading from the interaction gap in said last cavity to an electron collecting surface; a vacuum window structure for transmitting electromagnetic energy externally from said last cavity; cooling fluid means for circulating fluid adjacent said electron collecting surface in accordance with the power density distribution of electrons incident thereon and for circulating fluid adjacent said vacuum window structure, said output drift tube, said slotted tuning diaphragm, said drift tubes and said anode in accordance with the excess heat produced in these tube components under high power operation; a housing structure surrounding said electron gun; means for aligning said electron gun with respect to said anode and said desired axis comprising transition means supporting said gun within said housing, a transverse translation joint coupling said transition means to said housing and a longitudinal translation and angular rotation joint coupling said transition means to said electron gun; an insulating member separating two sections of said housing between which a high acceleration voltage is applied, at least one of said housing sections terminating in a corona shield surface; and a vacuum seal between said corona shield surface and said insulating member.

2. In a high power klystron tube apparatus the combination comprising: a permeable anode member adapted to accelerate a beam of electrons therethrough; an anode cooling channel adjacent the permeable portion of said anode; a plurality of spaced cavity resonators in the path of said electron beam and adapted for electromagnetic interaction with said beam; a plurality of drift tubes spaced along said beam path between said cavity resonators; a drift tube cooling channel adjacent each of said drift tubes; an output cavity resonator including a flexible tuning diaphragm; and output diaphragm cooling channel adjacent said flexible tuning diaphragm; an output drift tube along said electron path rearward of said output cavity resonator; an output drift tube cooling channel adjacent said output drift tube; an electron collector intercepting said electron beam and extending rearward of said output drift tube; a collector cooling channel adjacent the electron interception surface of said electron collector; an output window structure adapted to transmit electromagnetic energy from said output cavity resonator; a window cooling channel adjacent said output window structure; and means for circulating a cooling fluid to all of said cooling channels and removing excess heat generated in adjacent tube components thereby enabling long periods of tube operation at high power levels.

3. The combination according to claim 2 including a single inlet fluid fitting and a single outlet fluid fitting, means for distributing fluid into at least three parallel flow circuits between said inlet and outlet fittings, the first of said parallel circuits providing circulation to said window cooling channel, the second of said parallel circuits providing circulation to said collector cooling channel, the third of said parallel circuits providing circulation to said output drift tube cooling channel, to said output diaphragm cooling channel, to said drift tube cooling channels and to said anode cooling channel.

4. The combination according to claim 3 wherein said third fluid circuit includes two series flow circuit portions, the first of said portions providing circulation to said output drift tube cooling channel and the second of said portions providing parallel circulation to each of said output diaphragm, drift tube and anode cooling channels.

5. In a high power klystron tube apparatus the combination comprising: an electron collector; an output window structure; a body portion comprising an anode, a plurality of tunable cavity resonators and a plurality of drift tubes; window cooling means for circulating cooling fluid adjacent said window structure; collector cooling means for circulating cooling fluid adjacent said electron collector; body cooling means for circulating cooling fluid adjacent said body portion; and means for dividing a supply of cooling fluid between said cooling means in accordance with the heat generated in the tube components during high power operation.

6. The combination according to claim 5 wherein said collector cooling means is characterized by an optimum operating pressure and the fluid impedances of said window and body cooling means enable operation at said optimum pressure.

7. A collector for dissipating the energy of a high veloc-

ity beam of charged particles comprising: a cylindrical collecting surface concentric about the axis defined by said beam of charged particles, said collecting surface being terminated by a concentric conical end portion; and a cooling channel structure concentric with said collector, said cooling channel structure defining four series fluid flow zones spaced in the direction of said beam, said zones assuming the shape of a first cylinder, helix, second cylinder and cone, respectively, in the direction of said beam, said helical zone being limited to a region of maximum heat dissipation whereby the heat transfer characteristics of the cooling channel over said collecting surface are effectively matched to the power density of charged particles incident on said surface.

8. A collector according to claim 7 wherein said region of maximum heat dissipation is defined by the intersection with said collecting surface of the universal beam spread curve associated with said beam.

9. A collector according to claim 8 wherein said conical zone is bounded on the inside by said conical end portion and on the outside by a concentric truncated conical surface, the plane of truncation being forward of the apex of said end portion and the apex of said conical zone being rearward of said end portion apex, the angular measure of said zone apex being less than the angular measure of said end portion apex.

10. A collector for dissipating the energy of a high velocity beam of charged particles comprising: a collecting surface surrounding the axis of an incident beam of charged particles; and a cooling channel structure adjacent said collecting surface, said cooling channel structure being divided into a plurality of zones, one of said zones being adapted for helical flow of cooling fluid adjacent a limited section of said collecting surface characterized by maximum beam interception, thereby permitting efficient heat transfer with a minimum of total pressure drop across said collector.

11. A collector for dissipating the energy of a high velocity beam of charged particles comprising: a collecting surface surrounding the axis of an incident beam of charged particles; and a cooling channel structure adjacent said collecting surface, said cooling channel structure being divided into a plurality of zones, the heat transfer characteristics of said zones being effectively matched to the power density distribution of charged particles incident on said collecting surface.

12. In an electron tube apparatus the combination comprising: an electron gun providing a beam of electrons; a permeable anode spaced from said electron gun and adapted to accelerate said beam of electrons therethrough in a given direction; a housing member surrounding said electron gun; a longitudinally extending flexible U-shaped member fixedly secured to said electron gun; a transition member one end of which extends in a transverse direction and the other end of which extends in a longitudinal direction; and a flange member fixedly secured to said housing and extending in a transverse direction, the transverse end of said transition member abutting said transversely extending body flange whereby the portion of said electron gun facing said anode may be transversely aligned with respect to said anode and said given direction, the longitudinal end of said transition member abutting said longitudinally extending flexible member whereby said electron gun may be longitudinally positioned at a desired distance from said anode and whereby said flexible member may be slightly rotated to maintain the portion of said electron gun facing said anode in proper longitudinal alignment.

13. In a high voltage electron tube apparatus the combination comprising: a metal vacuum housing; and an insulating member separating two sections of said housing between which there is applied a high voltage, at least one of said housing sections terminating in an integral corona shield member having a T-shaped cross section (taken longitudinally along said housing), one arm of said T being integrally aligned with said one section of housing, the other arm and the leg of said T each terminating in a corona scroll, said insulating member being vacuum sealed to the leg of said T-shaped housing termination whereby said corona scrolls are positioned to prevent high voltage gradients and electron bombardment at said vacuum seal.

14. A combination according to claim 13 wherein both of said housing sections terminate in a T-shaped cross section, said insulating member being vacuum sealed to the leg of each of said T-shaped terminations and wherein the body-aligned arm of one of said T-shaped terminations further terminates in a transversely extending flange, said flange providing a reference surface for transversely aligning an electron gun within said housing.

15. A combination according to claim 14 further including a transition member having a longitudinally extending end and a transversely extending end, the transversely extending end of said transition member abutting said transversely extending flange and providing a transverse translation joint thereat, the longitudinally extending end of said transition member abutting a longitudinally extending flexible U-shaped member fixedly secured to said electron gun and providing a longitudinal translation and angular rotation joint thereat whereby said electron gun may be precisely aligned within said housing by fixedly securing said joints.

16. In a klystron tube apparatus the combination comprising: a cavity resonator; a drift tube structure adapted to pass a beam of electrons through said cavity resonator to enable electromagnetic interaction therewith; a flexible tuning diaphragm forming an end wall of said cavity resonator; driving means adapted to translate the end surface of said diaphragm; and a bendable portion of said diaphragm extending interior of said cavity resonator from said end portion, said bendable portion being fixedly secured to the side wall of said cavity at a position interior thereof and making contact with said wall only at said position.

17. The combination according to claim 16 wherein said cavity resonator is of the box-type and wherein the bendable portion of said diaphragm is fixedly secured to on pair of opposite side walls in said box and is adapted to slightly clear the other pair of opposite side walls in said box.

18. The combination according to claim 17 wherein said drift tube structure passes through said one pair of opposite side walls and forms an electromagnetic interaction gap therebetween.

19. An inductively tunable cavity resonator comprising: a cavity wall structure; and a flexible diaphragm having a translation surface and a bending surface, the translation surface of said diaphragm being adapted for back and forth movement in a direction extending through said cavity and the bending surface of said diaphragm extending interior of said cavity and being fixedly secured to said cavity wall structure at a position interior of said translation surface when in a fully retracted position, said bending surface making contact with said cavity wall structure only at said position of securing.

20. In a broadband klystron tube apparatus the combination comprising: a plurality of tunable cavity resonators adapted for electromagnetic interaction with a beam of electrons passable therethrough, each of said cavity resonators comprising a cavity wall structure of uniform size, said wall structure being enclosed by a flexible tuning diaphragm having a translation surface and a bending surface and said bending surface being secured to said wall structure at a position inward of said translation surface and making contact with said wall structure only at said position thereby permitting said cavity resonators to be stagger-tuned over a wide bandwidth.

21. In a high power klystron tube, the combination comprising: an electron collector; an output window structure; a body portion having as components thereof, an anode, a plurality of cavity resonators, and a plurality of drift tubes interconnecting said cavity resonators and said electron collector; body cooling means for circulating cooling fluid adjacent a plurality of said body components, said means including at least two parallel flow portions; and collector cooling means for circulating cooling fluid adjacent said electron collector in fluid flow parallel with said body cooling means.

22. The combination of claim 21 further including means for circulating cooling fluid adjacent said window structure in fluid flow parallel with said collector cooling means and said body cooling means.

23. The combination of claim 22 wherein said body cooling means includes two series flow portions, the first of said portions providing circulation to the drift tube interconnecting said electron collector, and the second of said portions providing parallel flow circulation to the other drift tubes and to said anode.

24. In a high power klystron tube apparatus, the combination comprising: a cylindrical cavity resonator adapted for high power electromagnetic interaction with an electron beam passable through the cylindrical surface of said cavity; a thin flexible tuning diaphragm in solid thermal contact with the entire circular periphery of said cylindrical cavity resonator and having a plurality of radial slots therethrough for relieving bending stresses upon movement thereof and eliminating pressure differentials on opposing surfaces thereof, said slots being limited to diametrically opposed diaphragm portions and running substantially parallel to that direction of current flow necessary to support the resonant mode of said

cavity resonator; a solid metallic plug member rearward of said flexible diaphragm in good heat conducting relation therewith; a tuning piston in solid thermal contact with said plug member for moving said diaphragm to thereby inductively tune the resonant frequency of said cavity resonator; a vacuum-sealing bellows secured between said tuning piston and said cavity resonator; and a cooling channel structure for circulating cooling fluid within said tuning piston.

25. The combination according to claim 16 wherein said bendable portion is doubly-flexed.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,054,925 September 18, 1962

Richard L. Walter et al.

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 2, line 46, for "corona second" read -- second corona --; column 3, line 71, for "warm" read -- worm --; column 6, line 40, after "amplify" insert -- signals --; column 10, line 43, for "on" read -- one --.

Signed and sealed this 20th day of August 1963.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents