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VOLTAGE TUNABLE MAGNETRON

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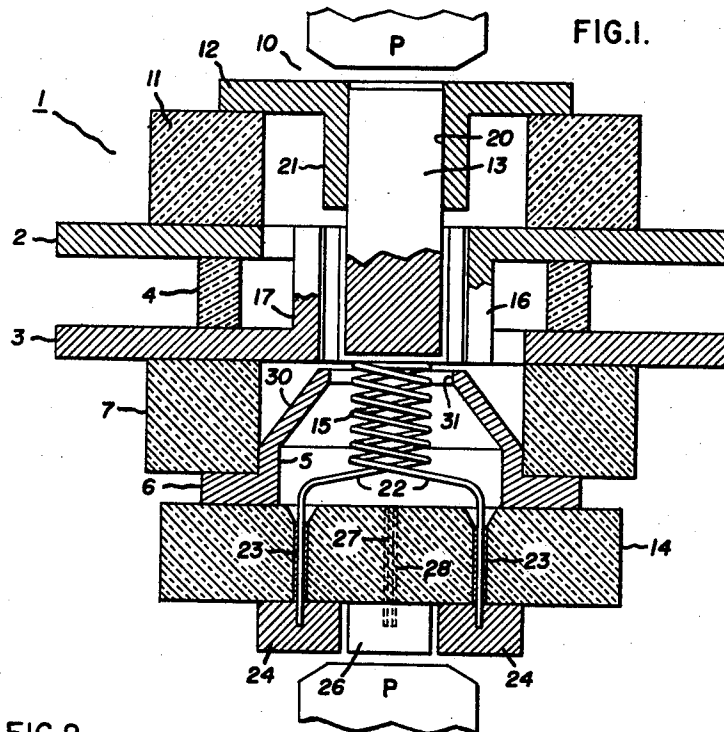
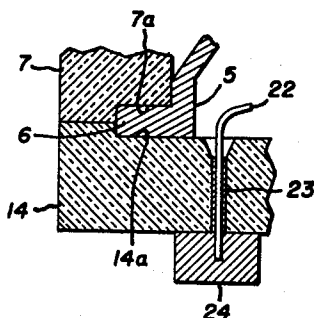
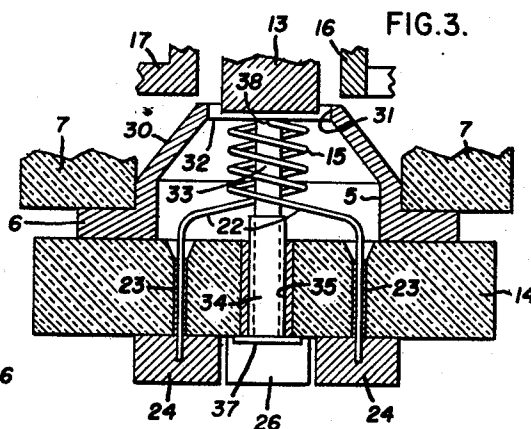
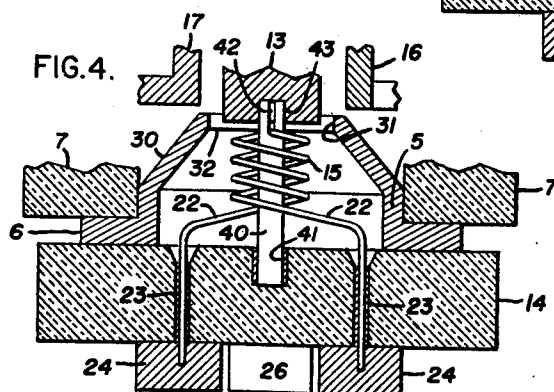


FIG. 2.



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VOLTAGE TUNABLE MAGNETRON

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11 Claims. (Cl. 315—39.63)

The present invention relates to an improved magnetron device tunable by variation of the anode-cathode voltage and more particularly to such devices including improved means for controlling the tuning and increasing the operating efficiency thereof and for better adapting such devices for operating under extreme vibratory and low-pressure atmospheric conditions.

In U.S. Patent No. 2,810,096, entitled "Voltage Tunable Magnetron With Control Electrode," to P. H. Peters, Jr., et al., and assigned to the same assignee as the present application, is described and claimed a voltage tunable magnetron having a control electrode for determining the power level at which the voltage tunable operation takes place. In accordance with that invention, the magnetron is provided with an emitting cathode area physically located outside of the oscillatory circuit, of which the anode is a part, and surrounded by a control electrode for determining the space charge within the anode and as a result of the output power level. The end of the control electrode is physically very close to the anode, in an axial direction, and is shaped to provide an axial component of field to assist in injecting the electrons from the region surrounding an emissive portion of the cathode and into an interaction space between the anode and the non-emissive portion of the cathode while at the same time keeping the electrons collected by the control element to a minimum. In the interaction space the movement of the electrons and the energy transferred therefrom is determined by the strength of the axial static magnetic field.

The present invention is in the nature of an improvement over the invention described and claimed in the aforementioned patent and relates to the provision of means adapted for insuring against adverse effects of filament current on the control of the device as effected by the mentioned control electrode and on the operation of the device as determined by the axial static magnetic field. Additionally, in the presently contemplated device the emissive and non-emissive portions of the cathode can be physically and electrically spaced enabling operation thereof at different potentials. Further, in the present device means can be included for rigidizing the mounting of the emissive cathode. Still further, the same rigidizing means can be employed, where desired, for electrically connecting the emissive and non-emissive cathodes and thus assisting in predetermining the field configuration in the region through which the electrons must pass by injection into the interaction space, thereby to facilitate such injection and minimize undesirable collection of electrons on the end of the non-emissive cathode. The present device is also better adapted through electrode dimensioning and disposition relative to insulative members for increasing and making indirect the creepage path between electrodes of different potentials, thereby better to adapt the device for high altitude operation.

Accordingly, an important object of our invention is to provide a new and improved voltage tunable magnetron

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including new and improved means for controlling the injection of electrons into the interaction space of the device, thereby to improve the controllability thereof.

Another object of our invention is to provide new and improved means for increasing the operating efficiency of a voltage tunable magnetron by minimizing adverse magnetic effects on the axial static magnetic field normally employed in the operation of the device.

Another object of the present invention is to provide, in a voltage tunable magnetron, a filamentary emitter whereby magnetic fields set up by a filament current therein are self-annulling or cancelling, thus to minimize adverse effects on the operation of the tuning means and thus on the radio frequency of the device.

Another object of the present invention is to provide, in a voltage tunable magnetron including a filamentary cathode, new and improved means for rigidizing the cathode and adapted for assisting in predetermining the field configuration in the region surrounding the cathode.

Still another object of the present invention is to provide a new and improved stacked arrangement of electrodes and insulator elements whereby production may be facilitated and the device is better adapted for high altitude operation.

Further objects and advantages of our invention will become apparent as the following description proceeds and the features of novelty which characterize our invention will be pointed out with particularity in the claims annexed to and forming part of this specification.

For a better understanding of our invention reference may be had to the accompanying drawing in which:

Figure 1 is an enlarged elevational view in section of a magnetron device embodying our invention;

Figure 2 is a fragmentary sectional view of a modified form of our invention;

Figure 3 is a fragmentary sectional view of another modified form of our invention; and

Figure 4 is a fragmentary sectional view of still another modified form of our invention.

Referring now to the drawing, there is shown in Figure 1 a magnetron device embodying a form of our invention. The device of Figure 1 includes an envelope generally designated 1 and constituted of a stacked assembly of alternately arranged metal and ceramic members wherein some of the metal members serve as electrical terminals of the device and the ceramic members serve as insulative spacers between the metal members. The metal members which serve as electrical terminals include a pair of annular anode terminals 2 and 3, separated by a ceramic cylinder 4. The metal members further include a frusto-conical control electrode 5 which will be described in greater detail hereinafter and which includes a flanged or annular portion 6 separated from anode terminal 3 by means of a ceramic cylinder 7 which is of a substantially greater outer diameter than the flange 6. The smaller diameter of the flange 6 relative to the ceramic 7 results in a substantially long and indirect electrical creepage path between the anode terminal 3 and the control electrode 5, whereby the structure is particularly adapted for preventing voltage breakdown and electrical leakage at reduced atmospheres. Thus, the device is particularly adapted for high altitude operation.

The envelope 1 is completed at one end by a composite end member 10 separated from the anode terminal 2 by a ceramic cylinder 11. The end member 10 comprises a centrally bored metal cap 12 in which is suitably fitted and bonded an internally extending post 13. The post 13 comprises the cold or non-emitting cathode assembly of the device which will be described in greater detail hereinafter, and the metal cap 12 comprises an electrical terminal therefor. Additionally, as illustrated,

the outer diameter of the cap 12 is substantially less than that of the ceramic insulator 11. This arrangement increases the leakage path between the cold cathode terminal and the anode terminal 2, and, thus, also adapts the device for high altitude operation. The other end of the envelope 1 is completed by a ceramic or disk 14. The disk 14 supports the hot cathode or electron emitter 15 of the device which will be described in greater detail hereinafter.

The magnetron device illustrated is of the interdigital type in which the anode assembly includes two sets of axially extending anode segments alternately arranged in a cylindrical array supported concentrically within the envelope 1 by the anode terminals 2 and 3. Alternate segments 16 and 17 are connected to different ones of the annular anodes 2 and 3, respectively, thus to provide two groups of anode segments alternately arranged in the array with each group connected to one of the terminals 2 or 3. The segments are slightly separated to provide axially extending interaction gaps. As is well understood in the art, it is the interaction between the high frequency fields across these gaps and the rotating and bunched space charge that effects the desired energy transfer from the space charge to the oscillatory circuit of the anode. As is also well understood in the art the electron rotation results from the provision of an axial magnetic field through the device. Such a field is usually provided by disposing the magnetron between the opposed poles P of a magnet in the manner illustrated in Figure 1.

In the embodiment illustrated, the electrons constituting the rotating beam are emitted from a portion of the cathode assembly disposed in a region of the envelope longitudinally displaced from the array of anode segments, and the entrance of the electrons into the region of the interaction gaps is under control of the control electrode 5.

As illustrated in the drawing, the cathode assembly includes the non-emitting cylindrical post 13 supported from the metal cap or terminal 12 and extending concentrically within the array of anode segments. As shown, the post 13, which may be referred to as the cold cathode, inasmuch as it does not emit electrons, is fitted in a central bore 20 in a concentric internally extending boss 21 formed on the cap 20. In this arrangement the cap 12 and the post 13 may be formed of titanium and the assembler of the device may easily adjust the desired extension or protrusion of the post into the envelope, lock the post in the desired adjusted position by spot welding and subsequently fully bonding the post in the end cap by brazing in a vacuum with the use of a nickel or copper ring between the post and end cap. As also shown, the boss 21 extends to the immediate vicinity of the array of anode segments and thus serves as an end shield for the interaction space. The post 21 extends longitudinally into the interaction space and terminates therein slightly inwardly of the lower end of the anode array, as viewed in Fig. 1. The axial spacing of the lower ends of the cold cathode and anode array is preferably about 10 mils.

Coaxially arranged in the lower end of the envelope 1 and longitudinally displaced from the lower end of the post or cold cathode 13 is the aforementioned hot cathode or emitter 15. The hot cathode 15 is of the directly-heated filamentary type and preferably is formed of thoriated tungsten wire and spaced about 10 mils from the cold cathode. The cathode 15 is bifilar and contra-wound or, in other words, comprises a double helix structure wherein the helices are mutually oppositely wound. In this structure both ends or leads 22 of the filament are disposed at one end thereof and the hot cathode is mounted and solely supported in the envelope by means of the leads 22. The leads 22 include portions which extend radially substantially from the axis of the cathode, thereby to increase stability and resist-

ance to vibratory movement, and downward extending portions which extend through and are suitably sealed in apertures 23 parallelly extending in spaced relation through the ceramic disk 14.

Connected to the outer extremities of the leads 22 is a pair of contact buttons 24. The buttons 24 are preferably formed of titanium and have the ends of the leads suitably brazed therein. Additionally, the buttons 24 are brazed to the outer surface of the ceramic disk 14 as by disposing a nickel shim between each of the buttons 24 and disk 14 and raising to a brazing temperature in a vacuum. The buttons 24 are effective for completing an electrical circuit through the contra-wound filamentary cathode, thereby to render same emissive and provide a cloud of electrons about the filament in the lower region of the device.

The just-described hot cathode arrangement including the bifilar contra-wound helices enables the hot cathode to be energized practically from either a D.C. or A.C. source. Thus, the device is not limited to the use of a D.C. source in operating the filament as is the case where a single helix or multiple helices wound in the same direction are provided. If an A.C. source were utilized with the latter type of filament, the fields set up by the filamentary current may deleteriously affect the R.F. operation of the device. In the contra-wound filament of the present device, the fields set up by the filament current are self-annulling or effectively cancel each other and, thus, are less apt to affect undesirably the radio frequency operation of the device. The particular manner in which this greatly enhances the operation of the presently disclosed device will be brought out in detail hereinafter.

As illustrated, the buttons 24 are disposed substantially inwardly of the edges of the ceramic disk 14, which arrangement serves to increase the leakage path to the anode contacts and adapts the device for high altitude operation. In the operation of the disclosed device, the electrons constituting the cloud surrounding the filamentary cathode are caused to enter or be injected into the interaction space between the non-emitting or cold cathode 13 and the cylindrical array of anode segments 16 and 17. This injection of electrons is under control of the control electrode 5 which will also be described in greater detail hereinafter.

Also brazed to the lower sides of the ceramic disk 14 is a control electrode contact button 26. The button 26 is brazed to the disk 14 in the same manner as the buttons 24. Additionally, the button 26 is suitably electrically connected to a tantalum or tungsten lead 27 which extends through and is sealed in a suitable aperture 28 extending through the disk 14 in parallel spaced relation to the aperture 23. The upper end of the aperture 28 opens directly beneath the flange 6 of the control electrode 5 and the upper or inner end of the lead 27 is suitably electrically connected to the flange 6, whereby the button 26 is adapted for serving as the contact for making an electrical connection to the control electrode 5. Additionally, the provision of the lead 27 extending through the ceramic disk 14 and the control electrode contact button 26 better adapts the device for high altitude operation by making it possible to avoid reliance on the flange 6 for making electrical contact to the control electrode, and, thus, enabling the outer diameter of the flange 6 to be reduced and disposed re-entrantly between the ceramic insulators 7 and 14. It will be seen from the foregoing and as illustrated in Fig. 2 that, if desired, the flange 6 can be completely imbedded in the envelope wall by being positioned in a counterbore or recessed edge 7a provided in the lower end of the ceramic insulator 7 and an annular recess 14a provided in the upper surface of the ceramic disk 14. Thus, the only possible external leakage path between the anode and the control electrode 5 would be the substantially

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elongated path extending between the anode contact 3 and the control contact button 26 over the outer surfaces of the ceramics 7 and 14.

The control electrode 5 includes, in addition to the flange 6, a tubular portion 30 extending from the flange 6 thereof toward the interaction space of the device. The tubular portion 30 is frusto-conical in shape and includes an inner surface which is spaced progressively closer to the filamentary cathode 15 in an axial direction toward the anode assembly. In operation, the control electrode 5 is maintained at a positive potential with respect to the cathode so that an axial component of velocity toward the interaction space is imparted to the electrons emanating from the hot cathode 15. As illustrated, the frusto-conical portion of the control electrode terminates in closely spaced relation to the anode. This spacing is preferably about 10 mils. Additionally, and as also illustrated, the control electrode is provided with a short internal cylindrical surface 31 adjacent the anode. The cylindrical surface 31 is preferably about 20 mils in length and has a diameter at least equal to and preferably smaller than that of the cylinder defined by the inner surfaces of the anode segments. This arrangement minimizes back-heating of the cathode and undesirable electron impingement and collection on the lower ends of the anode array and cold cathode.

The particular configuration of the control electrode and the particular spacing of the various portions thereof from the anode contribute substantially to its effectiveness in injecting a substantial number of electrons into the interaction space between the cold cathode 13 and the anode segment. This is particularly desirable in voltage-tunable magnetron devices since under the conditions existing during such operation the high frequency fields between adjacent anode segments are relatively weak in comparison with those existing in tank-tuned operation. In the specific embodiment of the device illustrated in Fig. 1, the wall of the control electrode extends at an angle of approximately 30 degrees with respect to the axis of the conical portion and the cylindrical portion 31 of the control electrode has an axial length of approximately 20 mils. The spacing between the face of the anode and the inner end of the control electrode is approximately 10 mils, and the inner end of the hot cathode extends beyond the control electrode and is spaced from the cold cathode approximately 10 mils.

In operation of the above-described device, a static magnetic field is provided by the magnetic poles P which field extends axially through the device. This magnetic field may be in the order of approximately 2500 gauss and is effective for rotating the electrons which are injected into the interaction space, thereby to effect the above-described energy transfer to the anode segments. The anode voltage at center frequency may be approximately 1150 volts, the filament current may be D.C. and approximately 3 amperes, and the control electrode potential may be +300 to +500 volts. Under these conditions of operation, the control electrode will be effective for injecting the electrons into the interaction space and the frequency of the device may be tuned by varying the potential between the anode and cathode.

It has been found that in voltage-tunable magnetron devices utilizing a single helix emitter or a multi-helix heater wherein the helices are wound in the same direction, magnetic fields are set up by the filament current which affect the main axial static magnetic field and thus cause undesirable proportional changes in the operating frequency of the device. Additionally, the magnetic field resulting from the filament current can have a radial component which affects the amount of electrons comprising the beam current injected into the interaction space by the control electrode 5 and thus undesirably

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change the radio frequency amplitude of the operating frequency and the operating frequency of the device.

In our device and as described above, the hot cathode comprises a bifilar contra-wound element or in other words, a double-helix filament wherein the helices are mutually oppositely wound. Thus, the magnetic field set up by the supply current thereof is self-annulling or, in other words, the contra-wound filament effectively cancels both components of the field established therebetween, and, therefore cannot have any of the above-described deleterious effects on the main axial static magnetic field or on the operation of the control electrode in injecting electrons into the interaction space. Thus, the device is adapted for improved operating efficiency.

In some applications the disclosed device is subject to considerable vibration. Under such conditions it is desirable to provide means for minimizing vibration of the filamentary cathode relative to the other electrodes. It is particularly desirable to minimize relative movement between the filamentary cathode and control electrodes since such movement would tend to result in non-uniform injection of electrons into the interaction space about the cold cathode and thus affect undesirably the tuned operating frequency of the device. In the sense that the tuned operating frequency of the device can be adversely affected by changes in the spacing between the cathode and control electrode, the operation of the device is most sensitive to motion of the cathode in the injection region. Additionally, excessive motion of the filamentary cathode can cause fatigue and resultant fracture thereof. Motion of the filamentary cathode is minimized and the cathode is made more stable by the disposition of the leads 22 substantially outwardly of the axis of the cathode in the manner shown in the drawing.

Illustrated in Fig. 3 is a modified form of our invention adapted for rendering more rigid the mounting of the filamentary cathode and thus minimizing any tendency toward vibration thereof and its undesirable effects. In this embodiment the same numerals designate the same or similar elements as those shown in Fig. 1 and described above.

However, as seen in Fig. 3, the relative longitudinal positions and spacing of the various electrode elements can be different. In the device of Fig. 3, control electrode 5 is spaced about ten mils from the anode, the upper end of the hot cathode 15 is about coplanar with the lower edge 32 of the 20 mils long cylindrical surface 31 of the control electrode, and the cold cathode 13 extends slightly into the control electrode and is spaced about 10 mils from the hot cathode. In this arrangement, substantially all electrons emanating from the hot cathode 15 are under the control of the electrode 5 in the injection of such electrodes into the interaction space.

The means provided for rigidizing the mounting of the filament 15 in the device of Fig. 3 comprise a support rod 33. The support rod 33 is centrally disposed in the contra-wound filament 15 and, as shown, is longitudinally spaced from and thus is mechanically and electrically disconnected from the cold cathode 13. The rod is preferably formed of molybdenum and is brazed in a tantalum tube 34 which, in turn, is fitted and brazed in a central aperture 35 extending through the filament disc 14. The outer end of the tantalum tube 34 registers substantially with the under side of the ceramic 14, and brazed to the outer end of the tube 34 as well as to the under side of the ceramic 14 is a titanium cap 37. This structure insures a vacuum-tight seal about the support rod and tube. Additionally, it enables advantage to be taken of the low heat conductivity of tantalum for eliminating hot spots in the filament ceramic which could cause cracking and leaking.

The inner end of the support rod 33 has the contra-wound filament secured thereto as by disposition of the

cross-over portion of the filament in an end slot 38 in the rod and either welding of the cross-over portion in the slot or crimping of the end of the post over the cross-over portion.

In the structure of Fig. 3, the support rod 33 rigidizes the mounting of filament 15, and, thus, tends to insure substantially uniform spacing between the filament and the control element and to maintain the filament and the cold cathode coaxially under conditions of vibration of the device. Thus, the device is adapted for insuring that the amount of electrons injected into the interaction spaced between the cold cathodes and anode assembly is substantially uniform about the circumference of the cold cathode whereby undesirable changes of the tuned frequency due to non-uniformity of the electron cloud entering the interaction space are minimized. Additionally, the mechanical and electrical isolation or disconnection of the filament and cold cathode avoid any possibility of noise problem due to uncertain electrical contact between the cold cathode and support rod which could occur where these elements are adapted for being in contact.

In some forms of the present device, however, it is desirable and advantageous from the mechanical and electrical standpoints to connect the filament support rod and cold cathode. Such a device is illustrated in Fig. 4 wherein, except for the just-mentioned difference, the structure is substantially similar and the same numerals designate the same or similar elements as those shown in Figs. 1 and 3. In this embodiment, the spacing of electrodes is the same as shown in Fig. 3. Additionally a molybdenum support rod 40 is provided. The support rod 40 is centrally disposed in the contra-wound filament 15 and the lower end thereof is fitted and brazed in a central recess 41 formed in the upper surface of the filament ceramic 14. The inner end of the rod 40 is provided with an end slot 42 in which is disposed the cross-over portion of the contra-wound filament. The cross-over portion of the filament is secured to the rod by either crimping the slotted end of the rod or welding the filament to the rod in the slot. In the final assembly the upper end of the post is fitted snugly in a central recess 43 in the lower end of the cold cathode. This type of fitting assures a satisfactory rigid electrical contact between the cold cathode and filament support rod and the arrangement is thus adapted for minimizing noise problems in the device that could result if a poor mechanical connection existed between these elements.

In the device of Fig. 4 the rod 40 enhances greatly the mechanical rigidity of the filament and also enables all electrical contacts below ground potential to be brought out of the envelope at one end thereof. The greater mechanical rigidity affords greater uniformity in spacing between the filament and control electrode during operation, thus to insure substantially uniform electron injection in the interaction space thereby to avoid undesirable frequency changes due to variations in electrode heat injection about the cold cathode.

Additionally, in the structure of Fig. 4 the non-emissive post or cold cathode 13 has a potential midway between the potentials of the filament terminals. This results in a unipotential conducting surface in both the axial and radial directions in the region where the electrons are injected into the interaction space. This type of cathode surface assists in providing a more uniform injection of electrons into the interaction space about the cold cathode thereby to minimize further any tendency toward undesirable changes in the tuned frequency due to non-uniformity in the amounts of electrons injected.

Still further, the structure of Fig. 4 is effective in reducing the impingement and collection of electrons on the end of the non-emitting post or cold cathode. In certain types of operation such a collection of electrons on the end of the cold cathode is considered undesirable and

subtracts from the operating efficiency of the device, and contributes to noise. Where such is the case, the structure of Fig. 4 can be utilized to great advantage.

It will be understood from the foregoing that, if desired, the cross-portion connecting the contra-wound helices can be secured directly to the end of the cold cathode 13, as by welding in a slot formed in the end of the cold cathode.

In the assembly of the structure shown, active alloy seals are preferably employed throughout. These seals can be effected by utilizing nickel-sealing shims between the titanium metal elements and between the titanium and ceramic elements forming a nickel-titanium eutectic seal and titanium sealing shims between the copper and ceramic elements, forming copper-titanium eutectic seals.

In production, the elements are preferably stacked with the appropriate sealing shims interposed therebetween and are brazed and sealed in a vacuum furnace at a temperature of approximately 1000° C. Preferably the portion of the device comprising the filaments and filament ceramic are assembled and placed as a separate sub-assembly which includes fitting the leads of the filament 15 and the control electrode lead 27 into the filament ceramic 14 and concurrently brazing the leads in the ceramic and brazing the contact buttons to the leads and the ceramic. In the embodiments including the filament support rods, the rods are brazed in their apertures or recesses during the same sub-assembly brazing operation.

The next assembly procedure leads to the assembly of the complete device. This involves placing the end cap 12 in a fixture, then setting the ceramic cylinder 11 on top of the member 12 with a nickel or copper sealing shim placed therebetween. Then the anode segment 2, ceramic spacer 4, anode segment 3 and ceramic spacer 7 are set in place in that order through appropriate guide posts on the fixture with titanium-sealing shims placed therebetween. Thereafter, the control electrode 5 is set in approximate position on and extending into the ceramic spacer 7 with a titanium shim therebetween. A stacked unit thus obtained is then inverted on a welding fixture. Then the post or cold cathode 13 is dropped into the aperture 20 in the end cap 12 with a nickel or copper shim thereabout, and the post is spot welded lightly in a desired spaced relation with respect to the end of the control electrode 5 and as determined by the fixture. The fixture is also adapted for centering the control electrode. Then the unit is inverted, the filament sub-assembly is set in place on the flange of the control electrode guided by the same posts which align the anode assembly and with a titanium shim therebetween. Thus, the brazing unit is completed for transfer into the vacuum furnace wherein the brazing operation is carried out for effectively brazing the various parts to bond same together and thus complete a vacuum-type device.

In assembling the modified structure of Fig. 4 the slotted end of the support rod 40 will be snugly fitted into the end of the post 13 when the filament subassembly is being placed into position. It will be seen that this fitting of the support rod in the cold cathode will have a desired effect of holding the brazing unit together until the brazing operation is complete.

It will be seen from the foregoing that we have provided improved voltage tunable magnetron devices adapted for better controlled voltage tuning, increased operation efficiency, ease in making circuit connections thereto, higher altitude operation and greater facility in high production manufacture.

While we have shown and discussed specific embodiments of our invention, we do not desire our invention to be limited to the particular forms shown and described, and we intend by the appended claims to cover all modifications within the spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A magnetron comprising an anode circuit including a plurality of segments supported in a cylindrical array in mutually spaced relation, a non-emissive electrode supported concentrically within the opening defined by said segments, a filamentary electron emissive electrode longitudinally displaced from said non-emissive electrode and constituted of a plurality of contra-wound electrically connected helices jointly defining a generally cylindrical structure, a control electrode surrounding said filamentary electrode, and means disposed between said non-emissive and emissive electrodes effective for minimizing electron impingement and collection upon the end of said non-emissive electrode.

2. A magnetron comprising an envelope, an anode circuit including a plurality of segments supported in a cylindrical array in mutually spaced relation, a non-emissive electrode supported in said envelope concentrically within and extending into the opening defined by said segments, a unipotential bifilar contra-wound filamentary emitter extending toward and spaced axially from said non-emissive electrode, a control electrode surrounding said filamentary emitter, said control electrode being closely spaced to said array, and said control electrode having an inner cylindrical surface of a smaller diameter than that of said opening defined by said segments, and an additional inner surface axially remote from said array and of larger diameter than said cylindrical surface.

3. A magnetron comprising an envelope, an anode circuit including a plurality of segments supported in a cylindrical array in mutually spaced relation, a non-emissive electrode supported in said envelope concentrically within and extending beyond the opening defined by said segments, a unipotential bifilar contra-wound filamentary emitter extending toward and spaced axially from said non-emissive electrode, a control electrode surrounding said filamentary emitter, said control electrode having an inner cylindrical surface of short axial length being partially coextensive with said non-emissive electrode and terminating at the outer edge in closely spaced relation to one end of said array and at the inner edge at a point substantially coplanar with the end of said filamentary emitter, and an additional inner surface axially remote from said array and of larger diameter than said cylindrical surface.

4. An electric discharge device comprising three insulative cylinders arranged in a stack, three annular metal members, each of a pair of said metal members being interposed between adjacent ends of different pairs of said insulative cylinders, a cylindrical array of anode segments supported from said pair of metal members within said insulative cylinders with alternate segments connected to one of said pair and the remaining segments connected to the other of said pair, a metallic cap at one end of said stack and a ceramic cap at the opposite end of said stack, the third of said annular metal members being interposed between said opposite end of said stack and said ceramic cap, a unipotential bifilar contra-wound filamentary emitter having all of the ends thereof extending through and sealed in said ceramic cap, and a control electrode surrounding said filamentary emitter and supported from said third of said annular metal members.

5. An electric discharge device according to claim 4, wherein contact elements are mounted in spaced relation on the outer surface and substantially inwardly of the marginal edge of said ceramic cap and have said ends of said filamentary emitter connected thereto.

6. An electric discharge device according to claim 4, wherein the third of said annular metal members has an outer diameter substantially less than the outer diameters of the insulative cylinder and ceramic cap between which it is interposed, an electrical lead is connected to

said third member and extends through and is sealed in said ceramic cap, and a contact element is mounted on the outer surface of said ceramic cap and has said electrical lead connected thereto.

7. An electric discharge device according to claim 4, wherein a non-emissive post is supported by said metal cap and extends toward said filamentary emitter in spaced relation to said anode segments, said control electrode and said metal cap have outer diameters substantially less than the outer diameters of the adjacent insulative cylinders.

8. An electric discharge device according to claim 4, wherein the insulative cylinder and insulative cap between which said control electrode is interposed include annular opposed recesses in which said third of said annular metal members is received thereby to imbed same in the wall structure of said device afforded by said insulative cylinder and cap.

9. A voltage tunable magnetron adapted for operating with a static magnetic field extending axially therethrough comprising an anode circuit including a plurality of segments supported in cylindrical array in mutually spaced relation, a non-emissive electrode supported in said envelope concentrically within the opening defined by said segments and cooperating with said segments to define an annular interaction space, a unipotential filamentary electron emissive electrode axially closely spaced relative to said interaction space, an annular control electrode surrounding said filamentary electrode and axially closely spaced relative to said interaction space, the opposed ends of said non-emissive and emissive electrodes, the adjacent ends of said anode segments and said control electrode defining an electric field at the end of said interaction space effective for controllably directing electrons axially from said emissive electrode into said interaction space, and said electron emissive electrode comprising only a single filamentary element including a pair of contra-wound helical portions, whereby said emissive electrode is effective for supplying electrons for direction into said interaction space with minimal introduction of undesired magnetic field components into the regions of said electric field and interaction space.

10. A voltage tunable magnetron according to claim 9 wherein said non-emissive and emissive electrodes are electrically spaced to enable operation thereof at different potentials.

11. A voltage tunable magnetron adapted for operating with a static magnetic field extending axially therethrough comprising an envelope defined by a stacked array of ceramic and metal elements, an anode circuit including a plurality of segments supported in cylindrical array in mutually spaced relation in said envelope, a non-emissive electrode supported from a metal end cap closing one end of said envelope and disposed concentrically within the opening defined by said segments and cooperating therewith to define an annular interaction space, a unipotential filamentary electron emissive electrode axially closely spaced relative to said interaction space, an annular control electrode surrounding said filamentary electrode and axially closely spaced relative to said interaction space, the opposed ends of said non-emissive and emissive electrodes, the adjacent ends of said anode segments and said control electrode defining an electric field at the end of said interaction space effective for controllably directing electrons axially from said emissive electrode into said interaction space, said electron emissive electrode comprising only a single filamentary element including a pair of contra-wound helical portions, whereby said emissive electrode is effective for supplying electrons for direction into said interaction space with minimal introduction of magnetic field components into the regions of said electric field and interaction space, and said filamentary element including integral leg portions at the ends of said helical portions extending parallel to the axis of said helical portions

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at diametrically opposed points spaced a substantial distance outwardly of said helical portions, and said leg portions extending through and being sealed directly in apertures in a ceramic cap closing the other end of said envelope, whereby said emissive electrode is stably 5 mounted for minimizing movement of said emissive electrode relative to the other electrodes defining said electric field.

12**References Cited in the file of this patent****UNITED STATES PATENTS**

2,324,972	Wright	July 20, 1943
2,462,858	Glauber	Mar. 1, 1949
2,522,419	Wing	Sept. 12, 1950
2,633,556	Kumpfer	Mar. 31, 1953
2,810,096	Peters et al.	Oct. 15, 1957