Aug. 19, 1952 R. B. NELSON 2,607,898

MAGNETRON

Filed Oct. 3, 1946 3 Sheets-Sheet 1

Fig. 1.

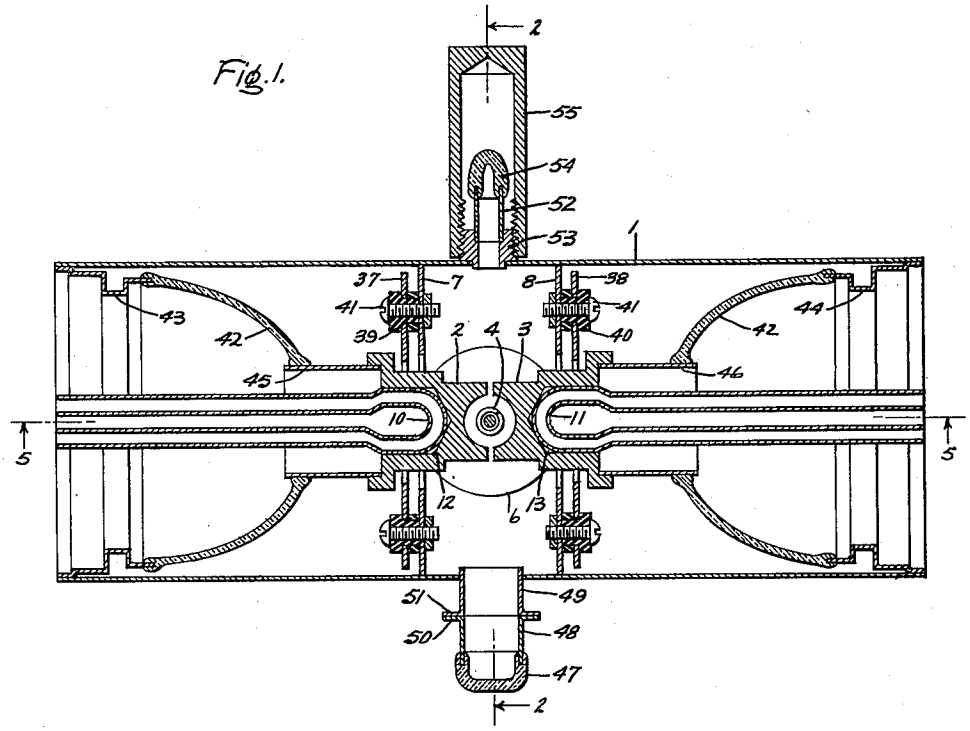
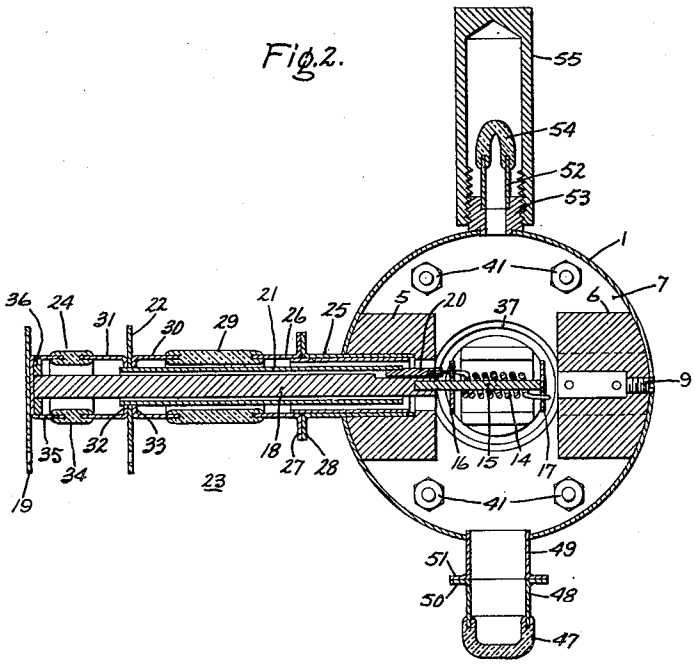


Fig. 2.



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Fig. 3.

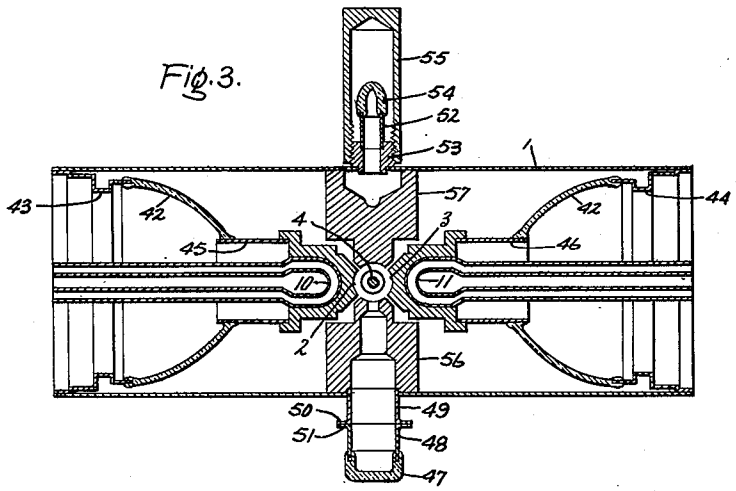


Fig. 4.

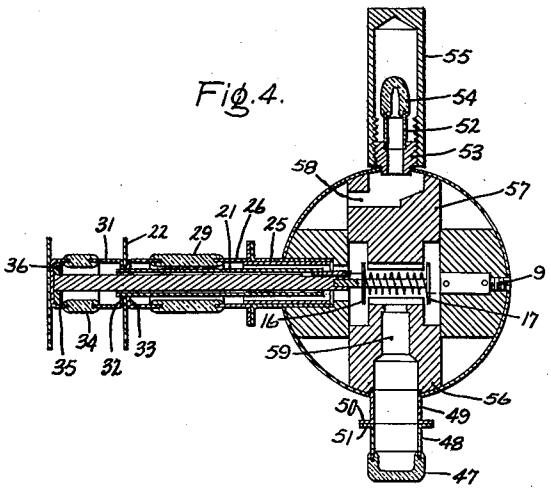


Fig. 5.

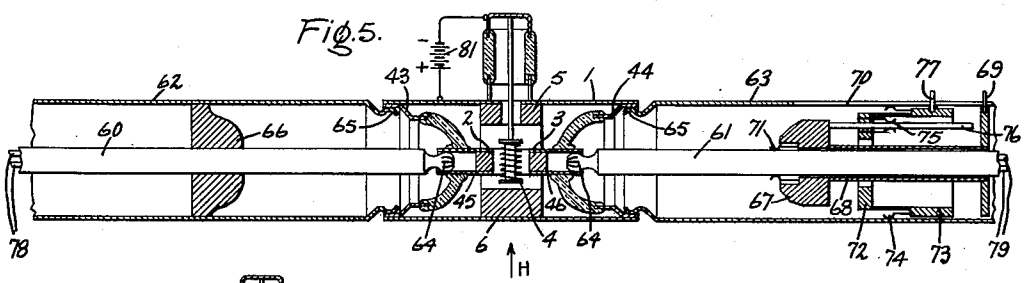
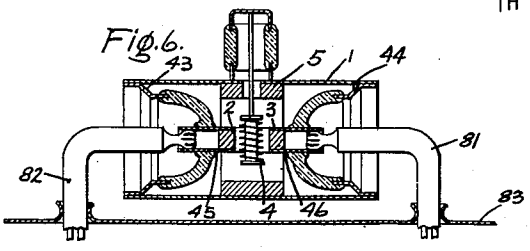


Fig. 6.



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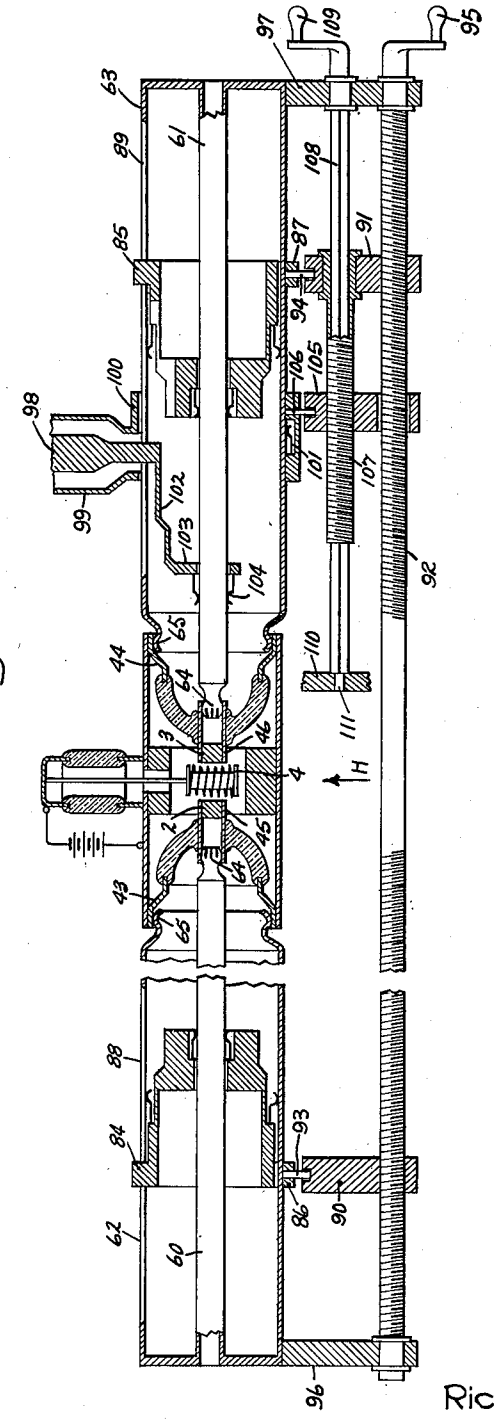


Fig. 7.

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UNITED STATES PATENT OFFICE

2,607,898

MAGNETRON

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Application October 3, 1946, Serial No. 700,939

21 Claims. (Cl. 250—36)

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This invention relates to electron discharge devices and oscillating circuits of the magnetron type and has for its object the provision of an improved tube construction having numerous advantages such as simplicity for manufacturing purposes, readily accessible and conveniently detachable external tuning means operable throughout a wide range of frequencies and improved relatively high power output, efficiency and operating life resulting from such features as an improved fluid cooling means, improved dielectric loss characteristics in the seals and minimized destructive bombardment of the envelope and seals by electrons escaping from the electronically active regions of the device.

It is a further object of the invention to provide an improved oscillating circuit in which the improved tube finds useful application.

The features of the invention desired to be protected are pointed out in the appended claims. The invention itself, together with its further objects and advantages, will best be understood from the following description taken in connection with the accompanying drawings in which Fig. 1 represents a cross sectional view of an illustrative magnetron discharge device embodying the invention; Fig. 2 represents a cross sectional view taken in the direction of the indicated arrows along a plane through the line 2—2 of Fig. 1 and vertical to the drawing; Figs. 3 and 4 represent similar cross sectional views of an alternative embodiment of the invention in a magnetron discharge device; Fig. 5 illustrates an oscillator employing discharge devices of the type shown in Figs. 1–4 and certain other features of the invention; while Figures 6 and 7 represent alternative constructions for oscillators or similar devices of the type exemplified in Figure 5. In the drawings like numerals have been used to designate like parts throughout.

Referring now to Figs. 1 and 2 it will be seen that the device comprises generally an hermetically sealed envelope 1, preferably of thin steel tubing, within which there are mounted a pair of magnetron anodes 2 and 3, a thermionic cathode 4 and a pair of magnetic pole pieces 5 and 6. The anodes 2 and 3 are provided with juxtaposed cylindrical faces defining a generally cylindrical chamber about and concentric with the axis of cathode 4 and the magnetic pole pieces 5 and 6 are so arranged as to establish, when suitably energized, a magnetic field parallel with the axis of the cathode within the cylindrical space defined by the anode faces. As will be well understood by those skilled in the art to which the invention pertains, the imposition of a relatively high positive potential on the anode with respect to the cathode will, in the presence of a sufficient magnetic field, establish a rotating electron space charge in the region defined by the anode faces and that such space charge will induce high frequency oscillations in the magnetron and its attendant circuits.

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The magnetic pole pieces 5 and 6 may be formed of any suitable magnetic material such as non-permanently magnetic soft iron or, if permanent magnets are desired, they may be of any suitable permanently magnetizable material such as the class of alloys of aluminum, nickel and cobalt generally known as Alnico. Alloys of this type are described for example, in Tokuschichi Mishima Patents 2,027,994 to 2,028,000, inclusive, and are further described in W. E. Ruder Patents 1,947,274 and 1,968,569. If non-permanent magnetic pole pieces are desired, any suitable means for magnetizing them may be provided externally of the envelope such as a pair of solenoids (not shown) juxtaposed to the envelope surface. In that event, the thickness of the enevelope 1 may be minimized in order to increase its magnetic reluctance thereby minimizing its shunting effect which tends to reduce the magnetic flux passing through the pole pieces. If, on the other hand, the pole pieces are permanent magnets thus providing an internal rather than external magnetizing force, the envelope will advantageously tend to minimize the magnetic reluctance of the useful magnetic circuit and consequently minimize the value of the required force. In that event its thickness may be maximized to the extent consistent with other design factors.

The pole pieces 5 and 6 may be welded or brazed to the envelope or fastened thereto by any other suitable means. Alternatively, they may be supported from the rings 7 and 8 hereinafter to be described or affixed by means of a bolt 9 as in the case of pole piece 6. Moreover, they are preferably shaped to conform to the contour of the envelope in order to minimize air gaps and thereby to minimize the magnetizing force necessary to establish the desired magnetic field.

For the purpose of providing forced cooling of the anodes 2 and 3 and adjacent structures when the discharge device is operated at a high-power output level, there may be provided a set of fluid coolant channels such as U-shaped tubes 10 and 11 of copper tubing which are built into externally accessible recesses 12 and 13, respectively, in the anode structure. The outer connections

to these tubes are, of course, accessible externally of the envelope and may be made through the center conductors of the co-axial output lines hereinafter to be described.

The cathode 4 may comprise any suitable construction. For example, as shown it is comprised of a helical coil 14 which may be of any suitable metallic wire such as tungsten and which may be coated with a suitable thermionically emissive coating as is well known in the art. Alternatively, it may be left bare of coating and operated as an uncoated thermionic filament. The coil 14 is supported on a rod 15 having end shields 16 and 17 which serve to enclose further the cylindrical space charge chamber defined by the opposing anode surfaces. As shown, one end of the coil 14 is conductively connected to the shield 17 and therethrough to rod 15, core 18, and externally accessible terminal 19, while the other is likewise connected through an intermediate connection 20 to tube 21 leading to an externally accessible terminal 22. The entire cathode structure may be supported by the concentric tubular construction 23 shown as projecting through the envelope 1 and into a cylindrical cavity in the pole piece 5. The construction 23 is comprised of a sectionalized outer cylinder 24, the inner metallic tube 21 and the central metal core or rod 18 which forms a conductive support for the cathode 4. Outer cylinder 24 comprises metallic cylinder 25 affixed to the pole piece 5 and envelope 1 as by brazing, cylindrical collar 26 welded by means of an end flange 27 to a similar flange 28 on cylinder 25, cylindrical glass seal 29, cylinder 30, cylinder 31 having an end flange 32 brazed to a similar end flange 33 on cylinder 30 with annular shaped terminal 22 in between the two, cylindrical glass cylinder 34 and cup-shaped collar 35. The cylinder 24 constitutes an hermetically sealed structure by virtue of the brazing at the metallic joints and suitable glass to metal seals at the glass to metal joints. Tube 21 is supported by brazing to the juncture of cylinders 30 and 31 and terminal 22 while core 18 is supported by brazing to collar 35, a metallic washer 36 furnishing additional support. Terminal 19 is provided on the end of the collar 35 for affording a suitable and convenient external contact for the cathode lead.

As will be understood by those skilled in the art, there is, in devices of this nature, a tendency for electrons to escape from the space charge rotating in the cylindrical region between the anodes and to migrate to other parts of the tube under the influence of the various electric and magnetic fields. In particular, the electric field due to the high frequency voltage on the anodes, can act in conjunction with the magnetic field to produce electron paths closely following the anode surfaces. These escaping electrons unless stopped will continue along the anode surfaces until they strike the glass seals, hereinafter to be described, and heat them to the melting point whereupon they destroy the device. This phenomenon is not only destructive of the discharge device as a whole but generally impairs its efficiency.

To prevent, or at least minimize this action, there may be provided a pair of annular suppressor disks 37 and 38 extending around the periphery of the envelope. Such disks may, for example, be formed of a suitable conductive material preferably one which is non-magnetic and which does not give rise to substantial secondary emission of electrons when bombarded by electrons. I have found disks of molybdenum satisfactory for the purpose. The disks may be mounted on insulating bushings 39 and 40 of quartz or like material. The bushings may in turn be mounted by means of nut and bolt structures 41 on the metallic rings 7 extending around the periphery of the envelope 1 and being welded or otherwise rigidly attached thereto. Upon being struck by escaped electrons the disks 37 and 38 will charge negatively until they repel subsequent escaped electrons and prevent them from reaching the glass seals. The effectiveness of these suppressor disks 37 and 38 has been found to be most satisfactory in that in all the discharge devices made thus far there have been no seal failures which could be attributed to electronic bombardments.

In order to provide a sealing structure in which the electrical field stresses created in the dielectric materials such as glass, by the oscillating fields are minimized, the connections to the respective anodes are preferably brought out opposite ends of the envelope where they may be conveniently connected to concentric line constructions hereinafter to be described. With such an arrangement the seal structure shown becomes possible. It comprises the vitreous seal members 42 of glass or like dielectric material bonded by suitable glass to metal sealing methods to metallic collars 43 and 44 and cylindrical members 45 and 46 supporting the anodes 2 and 3, respectively. The cylinders 45 and 46 will, of course, be brazed or otherwise hermetically and rigidly attached to cylindrical recesses in the respective anodes. The entire structures comprising the collars 43 and 44, the members 42, the cylinders 45 and 46, and the respective anodes may be fabricated as units after which the units are positioned within the envelope with the cylindrical surfaces of the collars 43 and 44 supporting the entire structures and positioning it in alignment with the axis of the envelope. Within the concavity formed by the seal construction the U-shaped copper tubes 10 and 11 may be supported by any suitable means such as by brazing to the anodes. They are shown as being fitted into cylindrical recesses in the anodes to facilitate supports.

The foregoing seal construction advantageously permits improved dissipation of heat developed in the dielectric seal members by reason of the fact that the seals are made as large as the envelope diameter and contact the heat dissipating metal surface of envelope 1 over a maximum area. Moreover, the heat energy developed within the dielectric as well as the electric fields therein are distributed more uniformly through the entire volume of the dielectric by virtue of the concentric relation of the inner and outer conductors of the coaxial output line hereinafter to be described. By way of contrast, it may be noted that in certain conventional types of seals wherein the output power of the device is conducted through the seal by two parallel non-concentric wires or like conductive rods (lecher wires) passing through a glass seal, the electric stresses and dielectric losses in the glass are concentrated in a narrow region between the two parallel wires thereby intensifying the destructive effects on limited portions of the dielectric. Moreover, it will be noted that the inverted dome shape of the seal permits sliding tuning members to approach relatively close to the anode of the device thereby permitting effective tuning to higher frequency and throughout a greater range

of frequencies in the manner hereinafter more fully to be described. For additional cooling, air may be blown through the center of the concentric conductors to cool the seals, the outwardly concave surface of the glass advantageously directing the outward flow of air and insuring more effective cooling contact between the air and glass than would be the case with an outwardly convex surface. That is to say, the cooling air naturally follows the concave surface in close contact therewith, whereas with a convex surface it would tend to be deflected away thereby tending to make only point contact.

For the purpose of permitting visual observation of the cathode where it may be desirable to take temperature measurements thereof by optical means, there may be provided a window **47** sealed to a metallic cylinder **48** by suitable glass to metal sealing methods. Cylinder **48** may be welded to a cylinder **49** by means of annular flanges **50** and **51** on the respective cylinders, the cylinder **49** being hermetically sealed through a suitable hole in envelope **1**. Alternatively, cylinder **48** may be hermetically sealed through such hole.

The described device may be hermetically sealed at all points and may be evacuated in known manner through a cylindrical tube **52** welded hermetically to a hollow threaded stud **53** likewise hermetically sealed to envelope **1**. Sealing after evacuation may be completed by glass bead **54** sealed across tube **52**. A protective cap **55**, threadedly engaging stud **53** may be provided to protect the structure from breakage.

In Figs. 3 and 4 there is shown another embodiment of the invention in a magnetron type discharge device employing also the principles of construction disclosed and broadly claimed in a copending application Ser. No. 601,126 of Donald A. Wilbur, filed June 23, 1945, for Electric Discharge Devices, and assigned to the same assignee as the present application. The characteristic feature lies in the provision of additional and electrically neutral electrodes defining with the anodes, such as the anodes **2** and **3** of Figs. 1 and 2, a cylindrical chamber within which the rotating electron space charge rotates. Except for the provision of such additional electrodes **56** and **57** in Figs. 3 and 4 and the optional omission of the annular rings **7** and **8** and annular shields **37** and **38** of Fig. 1, the construction shown in Figs. 3 and 4 is identical with that shown in Figs. 1 and 2. Therefore, in the interest of clarity, repetition of the description of the common features and enumeration of those features on the drawing has been omitted in Figs. 3 and 4.

Referring now to Figs. 3 and 4, it will be noted that an additional pair of electrodes **56** and **57** has been provided and that these electrodes define with the anodes **2** and **3** (corresponding to those of Figs. 1 and 2) a cylindrical chamber in which the electron space charge may rotate coaxially with the cathode **4**. Anodes **2** and **3** are, of course, modified in shape from that shown in Figs. 1 and 2 to permit the insertion of the electrodes **56** and **57**. The electrodes **56** and **57** may be conformed to the shape of the envelope **1** and affixed thereto as by brazing, welding or any other suitable means. Preferably the electrode **57** will be provided with a channel **58** providing a path for the outflow of gases during the evacuation process, while the electrode **56** may be provided with a channel **59** aligned with the window **47** to permit visual observation of the cathode, as hereinbefore described. The electrodes **56** and **57** will, of course, be electrically common with the envelope **1** and will be connected thereto at points which will assume electrically neutral potentials with respect to high frequency voltages on the envelope i. e. points having zero high frequency voltage such as nodal points of the standing wave set up in the envelope and its attendant resonant circuit during oscillation.

With the electrode configuration shown in Figs. 3 and 4 it will be found that for a given frequency of oscillation (which is, of course, always determined primarily by the inductive and capacitative characteristics of the external resonant circuit such as the resonant transmission lines hereinafter to be described), the angular velocity of the rotating space charge configuration will be only half of that for the construction of Figs. 1 and 2. According to the prevailing view of the manner of operation of magnetrons of the general type involved, this result arises from the fact that the rotation of the space charge tends to synchronize with the high frequency electromagnetic fields established in the vicinity of the gaps between the electrodes by the oscillations in the external resonant circuit. With the greater number of gaps, a smaller angular velocity is required to maintain synchronization since the space charge passes across the face of each electrode or anode in a half cycle of the frequency oscillation. In accordance with the principles set forth in the aforesaid Wilbur application Serial Number 601,126 the angular velocity can be made still lower by decreasing the angular extent of the faces of the anodes **2** and **3** and correspondingly increasing the angular extent of the faces of the electrodes **56** and **57**. Moreover, the effects desired can also be accomplished with but a single neutral electrode such as the electrode **57**. In the latter case the faces of the anodes **2** and **3** will be extended angularly to include the sectors shown in the Fig. 3 as occupied by electrode **56**.

As will be understood by those skilled in the art to which the invention pertains, the advantages of constructions such as are exemplified in the Figs. 3 and 4 will include a reduction of destructive and power wasteful effects of cathode back heating, simplified magnetic energizing means and the possibility of constructions capable of attaining higher oscillation frequencies. The first two of these advantages may be attributed primarily to the fact that the values of the magnetic and unidirectional electric fields required to energize the device may be reduced in proportion to the lowering of the angular velocity of the space charge configuration. Energizing fields of such lesser value may be established with simpler apparatus and will, because of their lower value, tend to reduce electron velocities which effect destructive back heating of the cathode. Conversely, constructions capable of attaining higher oscillation frequencies become possible because the correspondingly higher angular velocities of the space charge may be attained before the values of the necessary magnetic and unidirectional electric energizing fields become prohibitively high.

Fig. 5 illustrates more or less schematically an oscillator circuit in which the aforedescribed devices of Figs. 1 through 4 might find employment. For purposes of simplified explanation the devices of Figs. 1 through 4 are shown with certain details of construction omitted, for example, the cooling units and the details of the cathode heating circuit. However, Fig. 5 corre-

sponds generally to a cross section taken along the lines 5—5 of Fig. 1 in a plane perpendicular to the drawing except, of course, for the attached coaxial output lines presently to be described. In view of this correspondence, like numerals have been used to designate corresponding parts. For example, the anodes are designated 2 and 3, the magnetic pole pieces 5 and 6, the cathode 4, and the collars 43 and 44, as in Figs. 1 and 2.

Referring now to Fig. 5, it will be seen that there have been provided on both ends of the electrical discharge device coaxial transmission lines comprising respectively inner conductors 60 and 61, and outer conductors 62 and 63. Both the inner and the outer conductors are provided with a peripherally extending series of spring fingers 64 and 65 respectively. Fingers 65 resiliently engage the inner surface of the respective collars 43 and 44 in order to provide good electrical contact between the outer conductors 62 and 63 and the metallic envelope 1. The spring fingers 64 resiliently engage the inner surfaces of cylinders 45 and 46 to form good electrical contact with the cylinders and consequently with anodes 2 and 3. In effect the conductors 62 and 63 therefore form conductive extensions of the envelope 1, thereby forming with envelope 1, the outer conductor of a continuous concentric line. Inner conductors 60 and 61 effectively form in a similar manner a continuous inner conductor for the line broken only by the anode gap. As indicated in Figs. 1 and 2, the collars 43 and 44 may be shaped to receive conveniently the spring fingers 65. It will be observed that these constructions provide convenient means whereby detachable external connections may be made between the discharge device and suitable concentric output lines to be employed therewith. Such connections may be rapidly and conveniently detached should it be desired to replace the sealed device or to provide a different external circuit therefor.

For the purpose of tuning the device, for example, if it is employed as an oscillator, suitable shorting means electrically terminating the transmission lines on either side may be employed. In the case of the line comprising the conductors 60 and 62 the short is shown as comprising an annular-shaped tuning member 66 slidably mounted on the inner conductor 60 and so arranged as to engage both the inner and the outer conductor with good electrical contact. As is understood by those skilled in the art, the position of such tuning members longitudinally of the line determines the frequency of oscillation and the highest frequency which can ge generated by the arrangement is determined by how close the members can be brought to the anodes of the device. As already indicated hereinbefore, the dome-shaped seals of the device are inverted from their customary position so that the convex side is presented to the evacuated chamber. This feature allows the sliding shorts to approach very closely to the anodes and that distance is further shortened by appropriately shaping the shorts to fit within the concave surface of the seals. A similar short may be provided in the line comprising conductors 61 and 63.

For the purpose of providing a convenient means of deriving power from the oscillating anode tank circuit, i. e. that portion of the transmission lines between the shorts and the anode, the short on one side of the device may be made purposely "leaky" so that a portion of the tank circuit power will be transmitted through it instead of reflected. The transmitted portion will therefore flow beyond the short to an extended portion of the transmission line and thus to any further utilization circuits (not shown). Such a leaky short is shown internally of the transmission line comprising the conductors 61 and 63. It represents electrically a shunt inductance across the transmission line, variable by sliding its two parts relative to each other and thus changing the length of the shunt. It will be seen that it comprises an annular plunger 67 mounted upon a cylinder 68 closely fitting and sliding on the inner conductor 61 whereby the plunger 67 may be slidably positioned along the length thereof. The positioning may be accomplished by means of a manually operable stud 69 which is guided by a longitudinal slot 70 in the outer conductor 63. As indicated, the plunger 67 is of somewhat lesser diameter than the inner diameter of the outer conductor 63 and that therefore a certain amount of oscillatory energy may flow past the same to the external portions of the transmission line. Additionally, it may be provided with spring fingers 71 to insure good electrical contact with conductors 61. In order to vary the amount of leakage of energy past the plunger 67 an auxiliary sliding member 72 may be provided and mounted on a cylinder 73 which slidably engages the outer conductor 63 by means of spring fingers 74. A further set of spring fingers 75 within the cylinder 73 permits it to make firm electrical contact with the rod 76 conductively attached to the plunger 67 while in relative motion with respect thereto. Motion of the member 72 with respect to the plunger 67 is accomplished by means of the manually operable stud 77 guided by the longitudinal slot 70 in a manner similar to that of stud 69.

The foregoing structure will be found to provide a practical means of simultaneously tuning the transmission line comprising conductors 61 and 63 so that it may be tuned with the transmission line comprising conductors 60 and 62; and for simultaneously varying the amount of energy leaking past the short as desired.

It will be understood that suitable cooling means such as those hereinbefore discussed may be used for the purpose of cooling the anodes 2 and 3 and the seals adjacent thereto. Such means are indicated only schematically in Fig. 5 as the tubing 78 and 79 passing through the inner conductors 60 and 61 respectively to the vicinity of the anodes. The structure at the anodes will be that shown in Figs. 1 and 3. Additionally, air may be forced through the inner conductor by any suitable means (not shown) in order that it may pass into the space between the inner and outer conductors, thereby flowing past the glass seals in its path of escape to slot 70 or any other open portions of the lines.

It will also be understood that oscillations may be generated in the arrangement of Fig. 5 whenever it is energized by a suitable unidirectional electric potential imposed between the anodes 2 and 3 and cathode 4 in the presence of a suitable magnetic field directed perpendicular to the electric field i. e. a magnetic field directed generally parallel to the axis of cathode 4. The electric field may be provided by any suitable means such as battery 81 having its negative terminal attached to the cathode 4 and its positive terminal to the envelope 1 which is conductively connected to anodes 2 and 3 through the tuning means. The magnetic field represented by the arrow H may be provided by any suitable means (not shown) such as an electromagnet

positioned adjacent the envelope and pole pieces 5 and 6.

Fig. 6 illustrates schematically an alternative arrangement wherein the outer conductors in Fig. 5 have been omitted and the inner conductors now designated 81 and 82 are bent at right angles to the axis of the device in order that they may be brought out as parallel lecher wire transmission lines. The latter lines will form a standing wave resonant circuit for the device operating as an oscillator in a manner well known in the art. For the purpose of tuning a shorting rod or plate 83 may be employed across the lines in a manner well known in the art.

In Fig. 7 there is illustrated an oscillator which is substantially identical with that of Fig. 5 except for tuning means and the means for extracting power for the resonant tank circuit. Except for the latter means the corresponding elements have been designated by like numerals.

In order to insure that the tank circuit connection to both sides of the magnetron device are tuned to the same frequency at all points in the range of the oscillator, it is desirable that the tuning shorts in the respective transmission lines formed by conductors 60 and 62 in the one case and 61 and 63 in the other are symmetrically positioned. That is to say that the tuning shorts should be generally equally distant from the center of the magnetron device at all times. In the Fig. 7 there is shown a pair of tuning shorts 84 and 85 which tune the respective transmission line in the manner well known in the art. The tuning shorts are each mounted on an annular collar 86 and 87 slidably engaging the outer conductors of their respective lines. The tuning shorts may be connected to the collars 86 and 87 by means of an extension extending through longitudinal slots 88 and 89 in outer conductors 62 and 63 respectively. The collars 87 and 88 may be driven longitudinally of the transmission line by means of threaded members 90 and 91 which engage the threads of a crank rod 92 and which are connected to the collars 85 and 86 by means of suitable studs 93 and 94. The rod 92 is provided on either end with reverse threads in order that rotation of the rod will cause simultaneous movement of the shorts 84 and 85 away from the magnetron device, if rotated in one direction, and toward it if rotated in the other. For the purpose of rotating the rod there may be provided a crank on 95. It will be understood that the crank rod 92 will be fixed with respect to the oscillator structure by suitable means such as standards 96 and 97 attached to the ends of the respective transmission lines.

For the purpose of deriving useful energy from one of the tank circuits there may be provided a co-axial output line having an inner conductor 98 and an outer conductor 99 both of which are connected to any suitable energy utilization circuit (not shown). The outer conductor 99 may be connected to the outer conductor 63 by means of a collar 100 slidably mounted on the conductor 63 and having spring fingers 101 to insure a good electrical contact therewith. The inner conductor 98 may make sliding contact with the inner conductor 61 by means of the extension 102 terminating in the annular collar 103 which surrounds the conductor 61. Suitable spring fingers 104 may be provided to insure good electrical contact between collar 103 and conductor 61. The inner conductor 98 may enter the outer conductor 63 through the longitudinal slot 89.

It will be understood that the amount of power extracted by the line 98—99 from the oscillator will be dependent on the position of the collars 100 and 103 along the transmission line and for the purpose of varying that amount of power the line 98—99 may be positioned by sliding along the line 61—63. To that end, collar 100 may be adjustably positioned with respect to the tuning short 85 by means of a threaded member 105 which engages the collar 100 by means of a stud 106 and which is positioned with the respect to member 91 by means of the threaded sleeve 107. The sleeve 107 will be slidably mounted on a rod 108 in such a manner that it may slide freely in a longitudinal direction and yet be turned by rotary motion rod 108. To this end the cross-section of rod 108 and the internal cross-section of 107 may be rectangular. It will be noted that the sleeve 107 is fixed to the member 91 in order that the tuning short and the collar 100 will move in unison when ever the tuning is adjusted by means of the crank 95. The crank 109 will serve to rotate the sleeve 107 whenever it is desired to change the relative position between the output line 98—99 and the tuning short. It will be understood that the rod 108 may be similarly affixed to the standard 97 and to a fixed standard 110. It may be journalled therein by means of a pin 111.

As an illustration of the performance which may be obtained from oscillators embodying the aforedescribed invention, it is noted that in one such construction I have been able to provide an oscillator which will perform in a highly satisfactory manner over a frequency range varying from approximately 85 megacycles to 360 megacycles, i. e., a range of 4 to 1 in frequency. Generally the efficiency of arrangement was about 50% at all frequencies. The maximum power output varied from one kilowatt at the ends of this frequency range to about 3 kilowatts at its center.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. An electron discharge device of the magnetron type comprising an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material heremtically sealing each end of said portion, a pair of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection passing through one of said seal members, a cathode positioned within the chamber defined by said anodes, and means within said envelope supporting and positioning said cathode, said seal members having a generally convex portion extending inwardly of the ends of said envelope.

2. An electron discharge device of the magnetron type comprising an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, a pair of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes being supported from one of said seal

members in insulated relationship to said portion and having an externally accessible conductive connection passing through one of said seal members, a cathode positioned within the chamber defined by said anodes, and means within said envelope supporting and positioning said cathode, said seal members having a generally convex portion extending inwardly of the ends of said envelope.

3. An electron discharge device of the magnetron type comprising, an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a pair of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection passing through one of said seal members, a cathode positioned within the chamber defined by said anodes, and means within said envelope supporting and positioning said cathode and means for suppressing stray electrons from said space charge chamber comprising shield members positioned on either side of said space charge chamber in insulated relation to said portion and said anodes.

4. An electron discharge device of the magnetron type comprising, an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a pair of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection passing through one of said seal members, a cathode positioned centrally within the chamber defined by said anodes, and means within said envelope supporting and positioning said cathode and means for suppressing stray electrons from said space charge chamber comprising annular shield members positioned concentrically with said portion on either side of said space charge chamber in insulated relation to said portion and said anodes.

5. An electron discharge device of the magnetron type comprising, an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, a pair of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection passing through one of said seal members, a cathode positioned within the chamber defined by said anodes, means within said envelope supporting and positioning said cathode, and means within said envelope for establishing a magnetic field within said space charge chamber.

6. An electron discharge device of the magnetron type comprising an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, a pair of anodes within said portion having juxtaposed faces defining a generally cylindrical space charge chamber having an axis extending radially of said portion, each of said anodes being supported from one of said seal members in insulated relation to said portion and having an externally accessible conductive connection passing through one of said seal members, magnetic means affixed to the inner surface of said portion for establishing a magnetic field axially of said space charge chamber, a cathode positioned within the chamber defined by said anodes, and means within said envelope supporting and positioning said cathode.

7. An electron discharge device of the magnetron type comprising an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, a pair of anodes centrally within said portion having juxtaposed faces defining a generally cylindrical space charge chamber having an axis extending radially of said portion, each of said anodes being supported from one of said seal members in insulated relation to said portion and having an externally accessible conductive connection passing through one of said seal members, magnetic means aligned with said axis and affixed to the inner surface of said portion for establishing a magnetic field axially of said space charge chamber, a cathode positioned within the chamber defined by said anodes, and means within said envelope supporting and positioning said cathode.

8. An electron discharge device of the magnetron type comprising, an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a plurality of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of one pair of said anodes having an externally accessible conductive connection passing through one of said seal members, another of said electrodes being conductively connected to said portion, a cathode positioned within the chamber defined by said anodes, and means within said envelope for supporting and positioning said cathode.

9. An electron discharge device of the magnetron type comprising, an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a plurality of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of one pair of said anodes having an externally accessible conductive connection passing through one of said seal members, another of said electrodes being conductively connected to a longitudinal midpoint of said portion, a cathode positioned within the chamber defined by said anodes, and means within said envelope for supporting and positioning said cathode.

10. An electron discharge device of the magnetron type comprising an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a plurality of electrodes within said portion having juxtaposed faces defining a generally cylindrical space charge chamber having an axis ex-

tending radially of said envelope, a pair of said electrodes being supported each from one of said seal members in insulated relation to said portion and each having an externally accessible conductive connection passing through one of said seal members, at least one other of said electrodes being conductively supported from said portion, a cathode positioned within the chamber defined by said anodes, and means within said envelope for supporting and positioning said cathode.

11. An electron discharge device of the magnetron type comprising an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a plurality of electrodes centrally within said portion having juxtaposed faces defining a generally cylindrical space charge chamber having an axis extending radially of said envelope, a pair of said electrodes being supported each from one of said seal members in insulated relation to said portion and each having an externally accessible conductive connection passing through one of said seal members, another of said electrodes being conductively supported from said portion at a longitudinal midpoint thereof, a cathode positioned within the chamber defined by said anodes, and means within said envelope for supporting and positioning said cathode.

12. An electron discharge device of the magnetron type comprising, an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a plurality of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of one pair of said anodes having an externally accessible conductive connection passing through one of said seal members, each of another pair of said electrodes being conductively connected to said portion, a cathode positioned within the chamber defined by said anodes, and means within said envelope for supporting and positioning said cathode.

13. An electron discharge device of the magnetron type comprising, an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a plurality of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of one pair of said anodes having an externally accessible conductive connection passing through one of said seal members, each of another pair of said electrodes being conductively connected to a longitudinal midpoint of said portion, a cathode positioned within the chamber defined by said anodes, and means within said envelope for supporting and positioning said cathode.

14. An electron discharge device of the magnetron type comprising, an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a plurality of anodes within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of one pair of said anodes having an externally accessible conductive connection passing through one of said seal members, another of said electrodes being conductively connected to said portion, a cathode positioned within the chamber defined by said anodes, means within said envelope for supporting and positioning said cathode and means within said envelope for establishing a magnetic field within said space charge chamber.

15. An electron discharge device of the magnetron type comprising, an hermetically sealed envelope including a substantially cylindrical metallic portion and seal members of insulating material hermetically sealing each end of said portion, said seal members having a generally convex portion extending inwardly of the ends of said envelope, a plurality of anodes centrally within said portion having juxtaposed faces defining a space charge chamber within said envelope, each of one pair of said anodes having an externally accessible conductive connection passing through one of said seal members, another of said electrodes being conductively connected to a longitudinal midpoint of said portion, a cathode positioned within the chamber defined by said anodes, means within said envelope for supporting and positioning said cathode, and magnetic means within said envelope adjacent said anodes for establishing a magnetic field within said space charge chamber.

16. A generator of high frequency oscillations comprising in combination an electron discharge device of the magnetron type including an hermetically sealed envelope having a substantially cylindrical metallic wall, a pair of anodes positioned axially of said wall and having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection extending through an end wall of said envelope and a cathode in operative relation to said anodes, a line resonator comprising substantially cylindrical inner and outer concentric metallic conductors conductively connected to one end of said envelope, the outer conductor of said resonator being detachably connected to said wall and constituting a conductive extension thereof, the inner conductor of said resonator being detachably connected to one of said conductive connections and constituting a conductive extension thereof, means within said resonator conductively terminating said resonator at a predetermined point and means coupled to said generator for energizing said generator.

17. A generator of high frequency oscillations comprising in combination an electron discharge device of the magnetron type including an hermetically sealed envelope having a substantially cylindrical metallic wall, a pair of anodes positioned axially of said wall and having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection extending through an insulating end wall of said envelope and a cathode in operative relation to said anodes, a line resonator comprising substantially cylindrical inner and outer concentric metallic conductors conductively connected to one end of said envelope, the outer conductor of said resonator being detachably connected to said wall and constituting a conductive extension thereof,

the inner conductor of said resonator being detachably connected to one of said conductive connections and constituting a conductive extension thereof, tuning means within said resonator, means connected to said tuning means for adjustably positioning said tuning means longitudinally of said resonator whereby the frequency of oscillation of said generator may be varied, and means coupled to said generator for energizing said generator.

18. A generator of high frequency oscillations comprising in combination an electron discharge device of the magnetron type including an hermetically sealed envelope having a substantially cylindrical metallic wall, a pair of anodes positioned axially of said wall and having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection extending through an end wall of said envelope and a cathode in operative relation to said anodes, a pair of line resonators each comprising substantially cylindrical inner and outer concentric metallic conductors conductively connected each to one end of said envelope, the outer conductor of each said resonator being detachably connected to said wall and constituting a conductive extension thereof, the inner conductor of each said resonator being detachably connected each to one of said conductive connections and constituting a conductive extension thereof, means within each said resonator conductively terminating each of said resonators at predetermined points and means coupled to said generator for energizing said generator.

19. A generator of high frequency oscillations comprising in combination an electron discharge device of the magnetron type including an hermetically sealed envelope having a substantially cylindrical metallic wall, a pair of anodes positioned axially of said wall and having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection extending through an end wall of said envelope and a cathode in operative relation to said anodes, a pair of line resonators each comprising substantially cylindrical inner and outer concentric metallic conductors conductively connected each to one end of said envelope, the outer conductor of each said resonator being detachably connected to said wall and constituting a conductive extension thereof, the inner conductor of each said resonator being detachably connected each to one of said conductive connections and constituting a conductive extension thereof, tuning means within each of said resonators, means connected to said tuning means for adjustably positioning each of said tuning means longitudinally of said resonators whereby the frequency of oscillation of said generator may be varied and means coupled to said generator for energizing said generator.

20. A generator of high frequency oscillations comprising in combination an electron discharge device of the magnetron type including an hermetically sealed envelope having a substantially cylindrical metallic wall, a pair of anodes positioned axially of said wall and having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection extending through an end wall of said envelope, and a cathode in operative relation to said anodes, a pair of line resonators each comprising substantially cylindrical inner and outer concentric metallic conductors conductively connected each to one end of said envelope, the outer conductor of each of said resonators being detachably connected to said wall and constituting a conductive extension thereof, the inner conductor of each of said resonators being detachably connected each to one of said conductive connections and constituting a conductive extension thereof, tuning means within each of said resonators, means connected to said tuning means for adjustably positioning each of said tuning means longitudinally of said resonator at substantially equal distances from said space charge chamber whereby the frequency of oscillation of said generator may be varied and means coupled to said generator for energizing said generator.

21. A generator of high frequency oscillations comprising in combination an electron discharge device of the magnetron type including an hermetically sealed envelope having a substantially cylindrical metallic wall, a pair of anodes positioned axially of said wall and having juxtaposed faces defining a space charge chamber within said envelope, each of said anodes having an externally accessible conductive connection extending through an end wall of said envelope, and a cathode in operative relation to said anodes, a pair of line resonators each comprising substantially cylindrical inner and outer concentric metallic conductors conductively connected each to one end of said envelope, the outer conductor of each of said resonators being detachably connected to said wall and constituting a conductive extension thereof, the inner conductor of each of said resonators being detachably connected each to one of said conductive connections and constituting a conductive extension thereof, tuning means within each of said resonators, means connected to said tuning means for adjustably positioning each of said tuning means longitudinally of said resonators at substantially equal distances from said space charge chamber whereby the frequency of oscillation of said generator may be varied, means within one of said resonators for deriving energy therefrom, means connected to said last mentioned means for adjustably positioning said last mentioned means longitudinally of said one of said resonators, and means coupled to said generator for energizing said generator.

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