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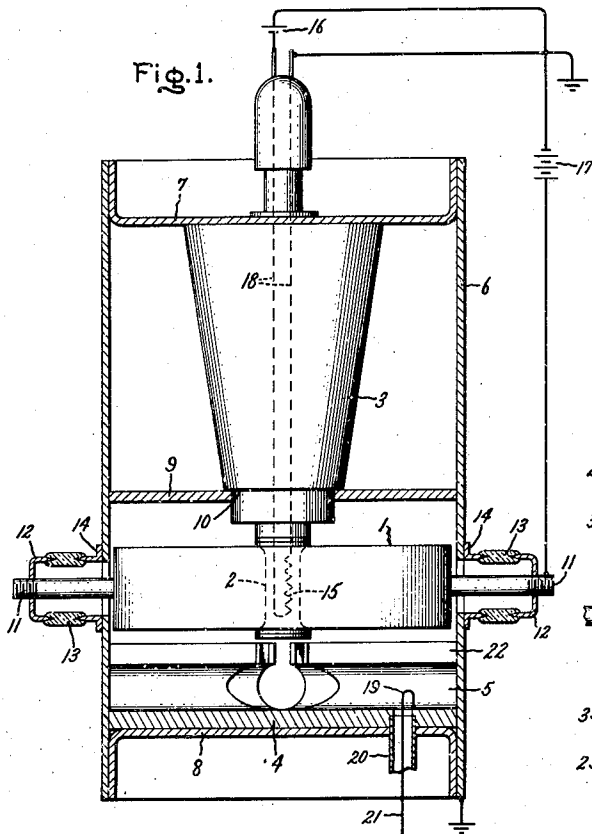
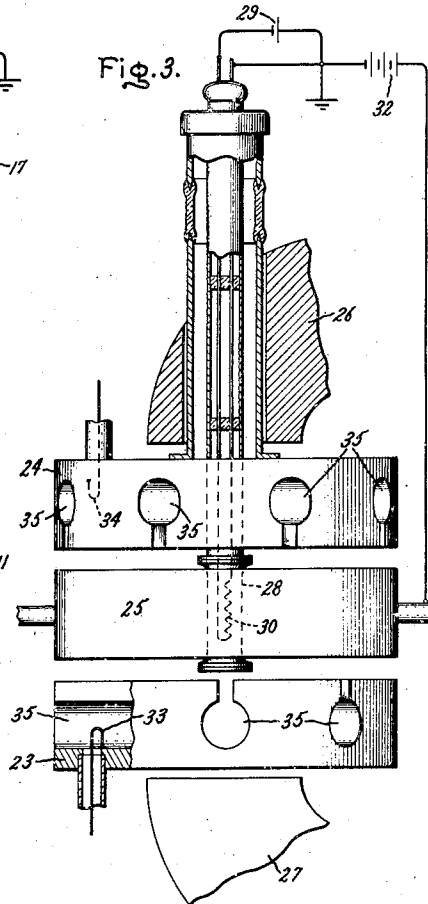
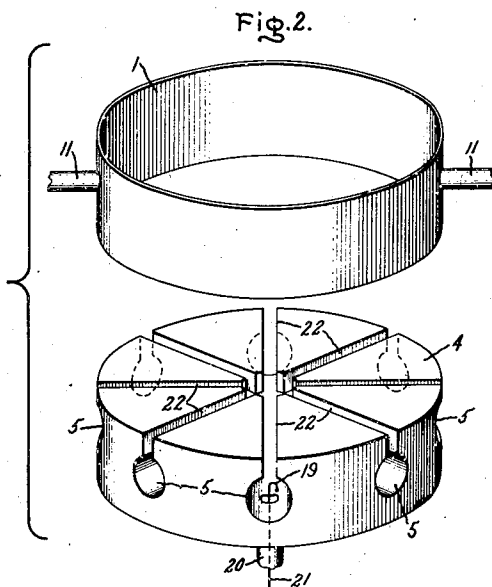
E. D. McARTHUR

2,485,401

MAGNETRON

Filed June 4, 1946

2 Sheets-Sheet 1



Inventor:
Elmer D. McArthur,
by *Harry C. Simkins*
His Attorney.

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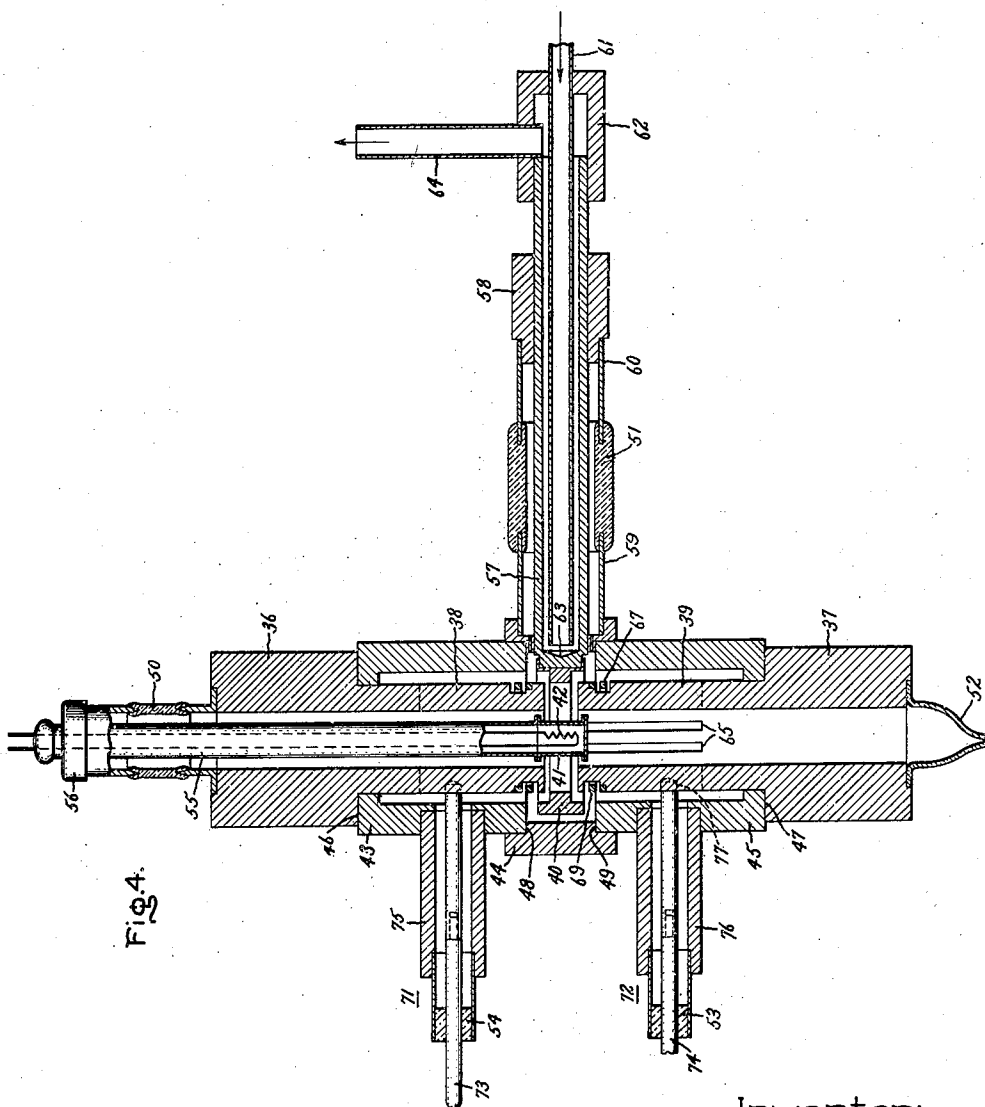
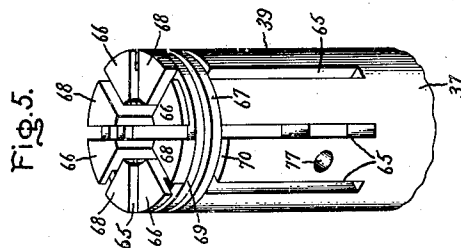
E. D. McARTHUR

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MAGNETRON

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2 Sheets-Sheet 2



Inventor:
Elmer D. McArthur,
by *Harry C. Dunsen*
His Attorney.

UNITED STATES PATENT OFFICE

2,485,401

MAGNETRON

Elmer D. McArthur, Schenectady, N. Y., assignor
to General Electric Company, a corporation of
New York

Application June 4, 1946, Serial No. 674,194

7 Claims. (Cl. 250—27.5)

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This application constitutes a continuation in part of my application Serial No. 447,903, filed June 22, 1942, now Patent 2,412,824, issued December 17, 1946, pertaining to an improved construction of the magnetic circuits of magnetron type discharge devices.

My present invention relates to electron discharge devices of the magnetron type, such as magnetron oscillators, amplifiers or reactance devices. More particularly it relates to a novel construction and operating arrangement for magnetron devices of the so-called cavity resonator type in which a rotating electron space charge induces or controls oscillatory phenomena in a plurality of cavities or resonant chambers spaced about the configuration of the space charge.

Heretofore, in the art of magnetrons of the foregoing type, it has been customary to employ constructions in which the plurality of cavities or like chambers are disposed in operative relationship to the cylindrical periphery of the space charge. Thus, in many exemplary constructions, they have been distributed in a generally cylindrical configuration, for example, by forming them as cylindrical cavities or sector shaped chambers on the inner wall of a generally annular anode and in parallel relation to the axis thereof. In such constructions, the annular anode was arranged to enclose a rotating space charge emanating from a central cathode positioned along the axis of the anode with the result that the cavities were parallel to the axis of rotation of the space charge and radially distributed about its cylindrical periphery. Such a construction is illustrated, for example, by the principal inventive embodiments described in the aforementioned application, Serial No. 447,903.

Now I have found that very desirable constructional and operational advantages may be obtained if in lieu of the foregoing arrangement the cavities are disposed in operative relation to an end surface of the rotating space charge. For example, they may comprise cylindrical cavities or like chambers having axes extending in spoke fashion along radii emanating from a point on the axis of rotation of the space charge adjacent to an end surface thereof. One such exemplary embodiment of the broad inventive concept is disclosed in the aforesaid application (Figs. 6 and 7). As further examples, there are disclosed in this application several more highly developed embodiments in which the cavities may be formed with axes extending in radial pattern within cylindrical end plates or cavity blocks constituting auxiliary electrodes juxtaposed to the bases of the annular anode common to the mentioned prior art constructions. Instead of being presented to the cylindrical periphery of the space charge as in prior art constructions indicated above, the cavities are thus juxtaposed to

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the end portions or end surfaces of the rotating space charge.

Among the advantages of this arrangement may be mentioned the fact that because the cavities are positioned in a new member which may be electrically and mechanically separated from the annular accelerating anode used to establish and maintain the rotating space charge, desired adjustments and manipulations of both the high frequency field and that of the accelerating anode may be accomplished independently of each other. Moreover, any objectionable collection of electrons of the space charge on the cavity structures is obviated, or at least minimized, for the same reason.

Accordingly, it is a general object of the invention to provide a magnetron device which utilizes the foregoing advantages to best avail and also to provide novel methods of operating magnetron devices which are made possible by the new construction.

The features of the invention desired to be protected herein are pointed out in the appended claims. The invention itself, together with its further objects and advantages, may best be understood by reference to the following description when considered in connection with the appended drawings in which Fig. 1 represents a view of a magnetron ensemble embodying the invention in a simplified form having a single cavity block adjacent to one base of the accelerating anode; Fig. 2 represents an exploded perspective view of the accelerating anode and the cavity structures of Fig. 1; Fig. 3 represents an alternative embodiment in which cavity blocks are positioned adjacent to both bases of the accelerating anode; Fig. 4 represents, in cross sectional view, an embodiment of the invention in a complete magnetron ensemble in which the cavities or resonant chambers take the form of radially extending rectangular slots in the cavity blocks or end plates; while Fig. 5 represents a perspective view of one of the cavity blocks of Fig. 4.

Referring to Fig. 1, the magnetron may comprise generally an annular accelerating anode 1, a cathode 2, positioned on the axis of the anode 1, a permanent magnet 3 or equivalent magnetic structure for establishing a magnetic field parallel to the cathode-anode axis in the usual manner, and an auxiliary electrode or cavity block 4 having radially extending cylindrical cavities 5. The entire ensemble is enclosed within an evacuated envelope 6 which may be of metal, of glass, or any of the equivalent materials common in the art, although metals of the ferromagnetic type are preferred for the reason that they will aid in the establishment of the necessary magnetic field.

The ends of the envelope 6, assuming it to be

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made of metal, are closed by flanged members 7 and 8 which are welded or otherwise hermetically joined to the inner surface of the envelope. The permanent magnet 3 may be suspended from the flanged member 7 and supported in addition by a transverse wall 9 of non-magnetic material having an aperture of size suitable for engaging shoulder 10 of the magnet in supporting relationship. The magnet 3 will provide the necessary magnetomotive force to establish the required magnetic field in the magnetic circuit including the magnet 3, the member 7, the envelope 6 and the block 4. To that end it is preferably formed of a magnetizable substance having a high coercive force and a high energy factor, such as the alloy known as Alnico described for example in Mishima Patents 2,027,994 to 2,028,000, inclusive, and further in the W. E. Ruder Patents 1,947,274 and 1,968,569.

The anode 1 may be supported by any suitable means as by lead-in members 11 which are supported in turn by metal caps 12. The metal caps 12 may be sealed to the envelope 6 by any suitable means such as glass to metal seals 13 and annular flanges 14. Block 4 may be suitably supported on flanged member 3 and welded to envelope 6. The cathode 2 which is preferably of the coated thermionic type may be supported in any suitable manner from the lower end of magnet 3. It may be heated by any of the conventional methods such as heater resistor 15 energized by battery 16 through the lead wires 18 extending through a central channel in magnet 3. The anode 1 may be energized by any source of unidirectional voltage such as battery 17 connected between the cathode 2 and the anode 1 by means of the lead-in member 11 and the wire connections shown.

For the purpose of tapping the output of the device where it is used as an oscillator, for example, an appropriate output coil 19 may be introduced into one or more of the cavities 5. The output is connected to a concentric transmission line having outer and inner conductors 20 and 21, respectively, which may connect with an antenna not shown or other agency for using the high frequency energy developed.

The construction of the auxiliary electrode or cavity block 4 is shown in clearer detail in Fig. 2. As shown therein, the block is of preferably cylindrical shape while the cylindrical cavities 5 are formed with elongated openings in the form of radial slots 22 opening into the space charge space between the accelerating anode 1 and cathode 2. The block may be constructed of any suitable metal, preferably a ferromagnetic metal, in order that it may serve as a portion of the magnetic circuit. All surfaces of the block 4 and, if desired, any other surfaces which may be within the field of the high frequency oscillations generated within the cavities 5, may advantageously be copper plated to reduce losses attributable to high frequency circulating currents induced by such fields.

In operation of the foregoing device, a rotating electron space charge of the well known magnetron type may be developed in the space between the cathode 2 and the accelerating anode 1 when a positive potential of suitable magnitude is applied to the anode by battery 17. As is well known, the space charge is created by the interaction of the radial electric accelerating field between anode 1 and cathode 2 and the axial magnetic field on electrons emitted from the cathode 2. According to the generally ac-

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cepted theory of magnetron operation, the passage or sweeping of electrons of the space charge past the slots 22 will induce in the cavities 5 high frequency oscillations of a frequency determined by numerous factors such as the distributed inductance and capacitance of the slots and the cavities, the voltage of the accelerating anode 1, and the strength of the magnetic field.

Referring now to Fig. 3, there is shown a further embodiment in which two electrodes or cavity blocks 23 and 24 are employed, one on either side of the accelerating anode 25 in order to utilize both end spaces of the structure. These cavity blocks may be identical in construction with the blocks shown and described in connection with Figs. 1 and 2. Permanent magnetic pole pieces 26 and 27 or their equivalent, are similarly provided in this construction. Preferably they too are formed of Alnico or equivalent material. The cathode 28 is energized by a source of heating current 29 and heater 30 in a manner similar to that of Fig. 1, while the anode 25 is similarly supplied with a source of energizing voltage by the battery source 32. It is to be understood that an evacuated envelope is to be provided as in Fig. 1 although for purposes of simplification of the drawing it is not shown in Fig. 3. In this construction, the output load may be coupled to either side of the device by means of the coils 33 and 34 which may be identical with the corresponding arrangement of Fig. 1. When the device is employed as an oscillator output power may be taken from both blocks 23 and 24 or one may be used as the output while the other is allowed to run free of load, in which case it will serve as a stabilizer supplying a certain amount of electrical inertia to the system to stabilize the oscillations, particularly the frequency of oscillation. Alternatively, the construction may be used as an amplifier, in which case the coil 33 might be used as an input and the coil 34 as an output, or vice versa. The cavities 35 in the respective cavity blocks may, in this construction, be angularly staggered or offset from each other in their radial planes. That is to say, the cavities of the upper block will occupy an angular position in between the angular position of the cavities in the lower block, as shown in the drawing.

The foregoing constructions will be found to exhibit a number of advantageous characteristics not found in prior art constructions. Among these may be noted the fact that the useful high frequency fields and the apparatus appurtenant thereto are now separated from the fields and apparatus used to maintain the rotating space charge. That is to say, the cavity blocks 4, 23 and 24, in which the useful high frequency phenomena occur, are mechanically and electrically independent of the accelerating anodes 1 and 25 with the advantageous result that necessary electrical or mechanical adjustments of either block or anodes may be accomplished independently. For example, I have found it possible where desirable to operate the cavity blocks at a potential different from that of the accelerating anode. Such operation was not possible in prior art constructions because the cavities were integral with the accelerating anode. A further advantage of the construction lies in the fact that it reduces the size of the necessary magnetic gaps with the result that the required magnetic field can be created more efficiently, that is, with a lesser magneto-motive force.

The further embodiment shown in Fig. 4, and

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in part in Fig. 5, comprises a pair of slotted end blocks 36 and 37 constituting auxiliary electrodes which are the counterparts of blocks 4, 23 and 24 of Figs. 2 and 3. The slotted inner portions 38 and 39 of the blocks 36 and 37 are constructed as shown more clearly in the perspective view of Fig. 5, which will be described in greater detail hereinafter. Those inner portions 38 and 39 are juxtaposed to the end surfaces of an annular accelerating anode 40 which is the counterpart of the anodes 1 and 25 of Figs. 1 and 3. Again as in Figs. 1 and 3, there may be provided a thermionic cathode 41 provided with a suitable heater 42 energized by any suitable source of current not shown through the lead-in connections shown.

The anode 40, the cathode 41, and the inner portions 38 and 39 are enclosed within an evacuated chamber formed by the annular wall members 43, 44 and 45, and the outer portions of the blocks 36 and 37. As shown, each of these members is provided with appropriate shoulder portions to which its adjacent member may be welded to form at the same time a hermetic seal and a rigid envelope for the device. For example, the blocks 36 and 37 are provided with shoulders 46 and 47 to which the members 43 and 45 are welded, respectively; while the member 44 is provided with annular shoulders 48 and 49 to which the annular wall members 43 and 45 may be welded, respectively. The chamber is further hermetically sealed by the glass to metal seals 50, 51, 52, 53 and 54 which may comprise any suitable sealing constructions well known in the art. The chamber may be evacuated at the seal 52 in the well known manner.

For the purpose of supporting the cathode 41 there may be provided within a central channel in the block 36 a cylindrical tube 55 supported in turn by collar 56 which is rigidly secured and positioned by the seal 50. A similar central channel is provided in the block 37 for the necessary connection between the evacuated chamber and the evacuated apparatus during the evacuation process.

The accelerating anode 40 may be supported by means of a tube 57 welded or otherwise attached to the anode 40 and protruding through an opening in the annular wall member 44. Tube 57 is supported by the collar 58 which in turn is supported from the wall member 44 by the seal 51 and the intervening collars 59 and 60. In order to provide cooling means for the anode 40 when operating conditions make such cooling desirable there is provided within the tube 57 a hollow tube 61 supported by annular jacket 62 rigidly secured to tube 57. Tube 61 is shown as extending into the tube 57 to a point just short of the closed end 63 of tube 57. A suitable outlet 64 to the jacket 62 is also provided. It will be apparent that any suitable coolant, such as water, may be circulated through the tube 61, the interspace between the tube 61 and the tube 57 and the outlet 64.

Turning now to Fig. 5 it will be seen that the inner portion 39 of block 37 is formed with a plurality of rectangular cavities or slots 65 having a parallelepiped shape and extending radially from the cylindrical central channel in portion 39. The inner portion 38 of block 36 is of substantially identical construction. In order to simplify manufacture, the slots 65 may be of rectangular cross section or other readily constructed shape. It will be understood by those skilled in the art that for most efficient operation of the device the natural resonant frequency of

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the slots 65 should be at least approximately equal to the desired frequency of operation of the device. Moreover, it will be understood that the natural resonant frequency of the slots will be dependent upon their physical dimensions such as their width and their length in the direction of the axis of portion 39. Therefore, the dimensions of the slots are preferably so proportioned as to give them a natural resonant frequency approximately equal to the desired operating frequency of the device. It will also be understood that the operating frequency of the arrangement will also be determined by the total number of slots and therefore the number is preferably chosen to suit the desired operating frequency.

In order to promote oscillation of the various slots 65 in unison and in proper phase, alternate sector portions 66 between the slots may be electrically interconnected to each other by conductive ring 67 while intermediate sector portions 68 between the alternate sector portions 66 are connected by a conductive ring 69. The rings 67 and 69 may be fitted into recesses 70 which are so shaped that recesses 70 in the alternate sector portions 66 will permit conductive contact between the sector portions 66 and the ring 67 while providing insulating spaced relation between the sector portions 66 and the conductive ring 69. Similarly the recesses 70 in intermediate sector portions 68 are so shaped as to permit conductive contact between the sector portions 68 and the ring 69 while providing insulating spaced relation between the sector portions 68 and the conductive ring 67. Recess configurations of this nature are already known in the art.

For the purpose of providing necessary input and output connections between the cavities or slots in the end portions 38 and 39 and external driving or utilization circuits, there may be provided the coaxial transmission lines 71 and 72 having inner conductors 73 and 74 and outer conductors 75 and 76, respectively. The inner conductors are sealed within the hermetic seals 54 and 53, respectively, to maintain the necessary evacuation of the magnetron. The outer conductors 75 and 76 are connected respectively to the annular wall members 43 and 45 while the inner conductors are conductively connected to one of the sector portions between the slots of their respective slotted end blocks. The latter connection may be made for example by inserting the inner conductor within holes 77 provided in one of the sectors as illustrated in Fig. 5.

It will be understood that in operation the magnetron will be provided with an appropriate magnetic field established by any suitable means such as external solenoids not shown, the magnetic field having a direction parallel to the axis of the blocks 36 and 37. In addition suitable unidirectional accelerating potentials may be applied to the anode 40 by any suitable means not shown and the cathode 41 energized as aforesaid. When such conditions exist the magnetron may be caused to establish a rotating electron space charge in the annular space between cathode 41 and anode 40. Moreover, it will be understood that the magnetron may be made to function as an oscillator, an amplifier or a reactance device depending upon the proper connections obvious to one skilled in the art. As with the arrangement of Fig. 3, either or both of the coaxial transmission lines 71 and 72 may be employed as output coils in the case of oscillator operation or, in the case of amplifier operation, one may be used as an input and the other as an output.

It will be noted that the above described construction is one which is relatively simpler to manufacture in that the slotted construction minimizes machining problems while the components are of simple configuration lending themselves to convenient fabrication and assembly. Moreover, it will be observed that the construction minimizes the magnetic gaps in the device and thereby provides for more efficient utilization of the magnetomotive forces necessary to set up the magnetic field.

It will be understood that the principles of the invention may be applicable to magnetrons employing different forms of cavity construction or their equivalents, such as the vane type in which the cavities or chambers are formed by radially extending vanes or, for further example, to magnetrons in which the cavities are positioned in asymmetrical distribution about the central axis of the anode-cathode as disclosed in an application Serial No. 601,121, filed June 23, 1945, by Ralph J. Bondley and assigned to the same assignee as the present application. This application became abandoned on June 29, 1948. Furthermore, while I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that numerous other changes and modifications may be made without departing from my invention in its broader aspects. 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. A magnetron of the cavity resonator type comprising a cathode, an annular anode surrounding said cathode, said cathode and anode forming a generally cylindrical space adapted to accommodate a rotating electron space charge, and a pair of auxiliary electrodes disposed on opposite sides of said anode and each having a plurality of cavity resonators opening into said space whereby high frequency oscillations may be induced in said resonators by said space charge, said resonators having longitudinal axes extending in a plane normal to the axis of said anode.

2. A magnetron of the cavity resonator type comprising a cathode, an annular anode surrounding said cathode, said cathode and anode forming a generally cylindrical space adapted to accommodate a rotating electron space charge, and a pair of auxiliary electrodes disposed on opposite sides of said anode and each having a plurality of cavity resonators opening into said space whereby high frequency oscillations may be induced in said resonators by said space charge, said resonators having longitudinal axes extending radially from a point on the axis of said anode and in a plane normal thereto.

3. An electron discharge device of the magnetron type comprising a cathode, an annular anode surrounding said cathode, said cathode and said anode defining a generally cylindrical space adapted to accommodate a rotating electron space charge having an axis of rotation coincident with said anode, and an auxiliary electrode having a plurality of cylindrical cavity resonators with openings juxtaposed to an end surface of said anode whereby high frequency oscillations may be induced in said resonators by said space charge, said resonators having longitudinal axes extending radially from a point on the axis of said anode and in a plane normal to said axis.

4. An electron discharge device of the magnetron type comprising a cathode, an annular anode surrounding said cathode, said cathode and said anode defining a generally cylindrical space adapted to accommodate a rotating electron space charge having an axis of rotation coincident with the axis of said anode, and an auxiliary electrode having a plurality of cavity resonators of parallelpiped shape with openings juxtaposed to an end surface of said anode whereby high frequency oscillations may be induced in said resonators by said space charge, said resonators extending radially from a point on said anode axis and in a plane normal to said axis.

5. A magnetron comprising an enclosure, a cathode within said enclosure, means within said enclosure including a magnetic pole piece for producing a magnetic field in proximity to said cathode, and a further body of ferromagnetic material positioned in opposed relation to said pole piece and in proximity to said cathode, said body being electrically resonant at the desired operating frequency of the magnetron and constituting a part of the return path for magnetic flux from said pole piece, and an anode.

6. An electronic device comprising an evacuated container constituted principally of ferromagnetic metal, a cathode within the said container, means including a magnetic pole piece within said container for producing a magnetic field in proximity to said cathode, said pole piece having a direct magnetic connection with said container, and a multi-cavity resonator of ferromagnetic material in opposed relation to said pole piece and in proximity to said cathode, said resonator having a low reluctance connection with said container and constituting a component of the return flux path for said pole piece, and an anode.

7. An electron discharge device of the magnetron type comprising an annular anode, a cathode coaxially mounted relative to the axis of said anode, said anode and cathode forming a generally cylindrical space adapted to accommodate a rotating electron space charge, and a pair of cavity resonators disposed on opposite sides of said anode and displaced therefrom along said common axis, each resonator comprising an electrically conducting member having a surface provided with radially extending slots of equal annular spacing, said surface forming said anode and the radii of said slots terminating on said common axis and the slots in one resonator being staggered relative to the slots in the other resonator.

ELMER D. McARTHUR.

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