Sept. 5, 1950 D. A. WILBUR **2,521,556**

MAGNETRON

Filed Nov. 20, 1946

Fig.1.

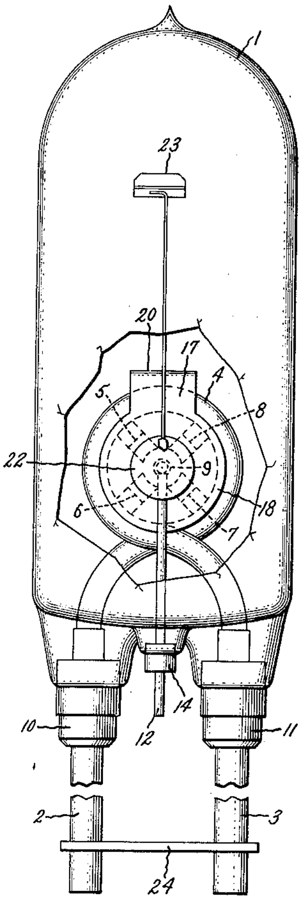


Fig.2.

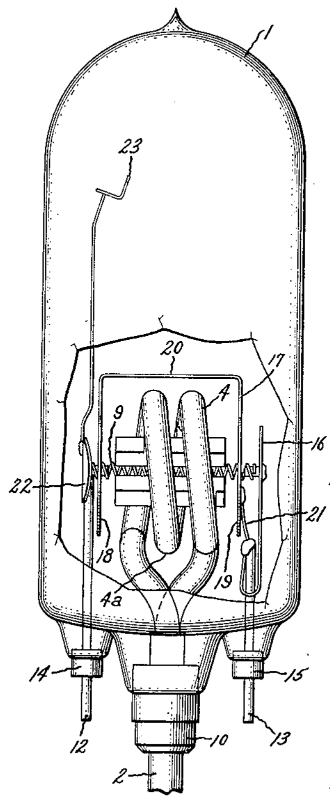


Fig.4.

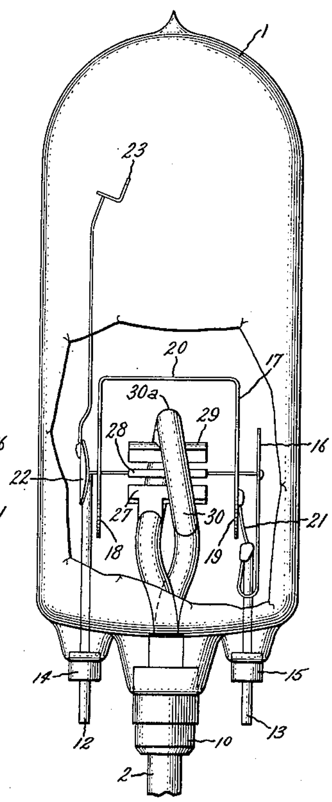


Fig.3.

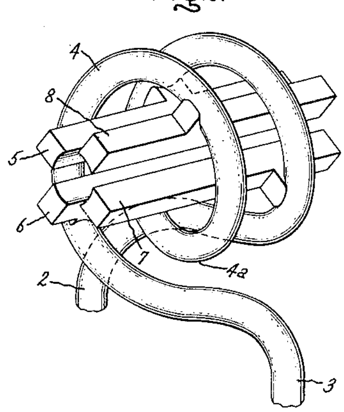
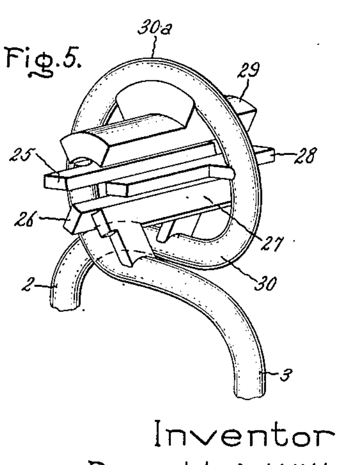


Fig.5.



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UNITED STATES PATENT OFFICE

2,521,556

MAGNETRON

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Application November 20, 1946, Serial No. 710,962

19 Claims. (Cl. 250—27.5)

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This invention pertains to electron discharge devices of the magnetron type and more particularly to a novel and improved construction which permits operation at higher frequencies and higher efficiencies.

Under the stimulus of the constant trend toward the use of higher and higher frequencies for electrical communications and related purposes, the art of magnetron discharge devices has in recent years developed extensively in the direction of multi-electrode constructions because of their inherent high frequency characteristics. In one type of construction, generally termed the resonant anode or cavity resonator type, a plurality of resonant cavities are disposed throughout an annular block anode surrounding the periphery of a rotating space charge, the cavities communicating with the space charge in such manner that high frequency oscillations are induced in them by the rotation of the space charge. Principal among the advantages of such constructions have been the higher frequencies and higher efficiencies obtainable. However, they also exhibit certain inherent drawbacks which limit their usefulness. Among these may be mentioned: the troublesome tendency of individual cavities having small unavoidable differences in dimension to oscillate at different natural frequencies whereby the ensemble produces a narrow band of frequencies where but one is desired; the fact that the ensemble, because of its geometry, may oscillate in any of several different modes having closely related frequencies which fact introduces frequency stability problems; the difficulty in devising satisfactory tuning systems to tune all cavities in unison when it is desired to change the operating frequency of the oscillator; and the manufacturing difficulties involved in the highly precise dimensioning of the large number of cavities.

In another type of magnetron construction which has been widely used, a pair of mutually spaced anode members is provided with opposed semi-cylindrical surfaces which define a generally cylindrical boundary confining the rotating space charge of the device. Conductors of a parallel wire transmission line are connected, respectively, with the anode members and extend through the envelope of the device to external circuits. In such constructions the operating frequency is determined not by the electrode structure, as in the cavity resonator type, but rather by the parameters of the transmission line constituting an external tuning circuit for the magnetron. The operating frequency is

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therefore readily controlled by adjusting the position of a short circuiting conductor connecting the conductors of the transmission line.

Magnetrons having the last mentioned construction have been referred to as the split anode type. These devices have been satisfactory for many applications and the simplicity of the tuning arrangement has been an outstanding advantage over magnetrons of the cavity resonator type. Its general constructional simplicity has been a further advantage from the viewpoint of manufacture. However, it has exhibited the undesirable feature that its frequency range is in general considerably lower than that of the cavity resonator type, this because of the fact that it has fewer electrodes to sustain oscillation. Heretofore, because of structural complexity, it has not been practicable to effect any substantial increase in the number of anode elements for the purpose of raising the frequency range.

I have found, however, that by certain constructional features to be hereinafter described, it is possible to construct a magnetron of this general type which retains the simplicity of the split anode type particularly with respect to tuning and manufacture and which, at the same time, provides to a substantial degree the higher frequency characteristics of the cavity resonator type. At the same time, it avoids to a substantial degree certain undesirable characteristics of the cavity resonator type, such as those aforementioned.

Accordingly, it is the general object of my invention to provide a new and improved magnetron construction characterized by higher operating frequencies, fewer undesirable modes of oscillation, higher efficiencies, and simplicity of construction and operation.

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 taken in connection with the accompanying drawing, in which Fig. 1 represents a view, partly in section, of a magnetron discharge device embodying the principles of the invention; Fig. 2 represents a side view of Fig. 1; Fig. 3 represents a perspective view of the electrode structure of Fig. 1; Fig. 4 represents a further embodiment of the invention incorporating certain additional features; and Fig. 5 represents a perspective view of the electrode structure of Fig. 4. Like numerals have been used to designate like parts throughout the drawing.

Generally speaking, I accomplish the object of my invention by mounting the anodes in angular radial distribution along the inner surface of a spiral tubular coil, the ends of which adjoin one end of the transmission line forming the tuning and output circuit of the magnetron. By electrically connecting the alternate anodes to appropriate different points on the spiral it is possible to obtain the proper distribution of high frequency potentials among the anodes which is necessary to initiate and sustain oscillations of the desired frequency.

Referring now to Figs. 1, 2 and 3, there is shown a magnetron comprising generally an hermetically sealed envelope 1, enclosing a part of a resonant circuit such as a transmission line formed by the conductors 2 and 3 extending through the envelope 1 and a two turn spiral coil 4 which terminates the conductors. Within the spiral coil 4 there are provided a plurality of anode electrodes 5, 6, 7 and 8, each of which is conductively supported from a different point on the inner periphery of the spiral 4 as by welding thereto. As is seen from the drawing, the anode electrodes are positioned in a generally cylindrical configuration by virtue of their attachment to the spiral. Centrally of the spiral 4 and therefore likewise centrally of the anode electrodes there may be provided a thermionic cathode of any suitable type. In the drawing the cathode is shown as comprising a spiral tungsten coil 9 which may be coated with a suitable thermionic emissive material of the types well known in the art.

Conductive connections may be made to the spiral 4 through the envelope 1 by means of any suitable hermetic glass to metal seals such as the seals 10 and 11 surrounding the lines 2 and 3 and permitting them to pass through the envelope wall. Similarly, conductive connections may be made to the cathode coil 9 by the leads 12 and 13 which pass through the envelope wall at similar glass to metal seals 14 and 15. The cathode coil 9 may be rigidly attached to the lead 12 at one end and at the other end to a spring tension member 16 rigidly secured to the lead 15. It will be understood that the spring member 16 will hold the cathode coil 9 taut and fixed in its position relative to the spiral and anode structures.

For the purpose of precluding excessive destructive bombardment of the envelope 1 and the lead-in seals by electrons escaping from the generally cylindrical space charge region defined about the cathode by the anode electrodes, there may be provided a cathode end shield 17 having flat annular end members 18 and 19 surrounding the cathode at one end and juxtaposed to the respective end faces of the anodes. The members 18 and 19 may be joined by an integral cross bar 20 for rigidity and for support. The entire structure may be fixedly positioned and supported within the envelope by means of a support 21 welded to the lead-in member 13 and to the member 19. An additional end shield 22 may be provided on the lead 12 and the upper end of the spring member 16 may be shaped to effect a similar result at the other end of the cathode if desired. A suitable getter may be provided on a getter support 23 welded to the lead 12 or to the shield 22. The getter may be flashed in the well known manner during the evacuation process.

As indicated more clearly in Fig. 3, the anode electrodes 5, 6, 7 and 8 are conductively supported from the spiral as by welding thereto at different points on its inner periphery. For example, it will be seen that the electrodes 6 and 8 are connected to the spiral at points displaced by 180° from each other on the first turn of the spiral while the electrodes 5 and 7 are similarly displaced from each other by 180° on the second turn of the spiral, the anodes 6 and 8 being symmetrically interpositioned between the anodes 5 and 7 as shown. The electrodes are preferably positioned symmetrically about the axis of the envelope, i. e., they are positioned about 45° along the spiral from the intersection with the spiral coil of a plane through the axes of the envelope 1 and the spiral coil itself. Thus it will be seen that as one proceeds around the periphery of the anode configuration, alternate anode electrodes may be considered as connected to points which are on a lengthwise half of coil 4 on one side of its lengthwise mid-point 4*a*, while the anode electrodes intermediate between those alternate ones may be considered as connected to points on the lengthwise half of coil 4 on the other side of its lengthwise mid-point 4*a*. If, therefore, one lengthwise half of the coil becomes electrically positive and the other negative at any instant during high frequency oscillation of the tank circuit comprising the transmission line, then the electrodes 5, 6, 7 and 8 will be alternately positive and negative.

The spiral coil 4 and conductors 2 and 3 may advantageously be constructed of a continuous length of hollow metal tubing, for example, copper tubing. Thereby there is provided a channel through which a coolant such as water or equivalent fluid may be circulated for the purpose of cooling the anode electrodes.

It will be understood that in operation a relatively high unidirectional voltage may be imposed between the cathode coil 9 and the anode electrodes 5, 6, 7 and 8, the cathode being negative with respect to the anode electrodes, and that a magnetic field parallel to the cathode and anode electrodes will be provided by any suitable means not shown such as external magnets juxtaposed to the envelope surface. As will be well understood by those skilled in the art to which the invention pertains, the interaction of these electric and magnetic fields will induce a rotating electron space charge of the magnetron type in the generally cylindrical space defined by the inner faces of the anode electrodes. It will also be understood that the interaction between the rotating space charge and the anode electrodes will set up high frequency oscillations and standing waves in the resonant transmission line comprising spiral coil 4 and conductors 2 and 3. The frequency of oscillation will be determined primarily by the characteristics, for example the length, of the transmission line and may be controlled by any suitable means such as a tuning short 24 slidably positionable along the length of the external portion of the transmission line.

The foregoing construction obviously presents four gaps formed by the four electrodes and for normal oscillation of the tank circuit formed by the transmission line, the instantaneous high frequency voltages of alternate electrodes will be positive and negative. The position and direction of the fields in the gaps are thus the same as those in a four gap magnetron and four gap action is obtained. Thus the employment of the four electrodes 5, 6, 7 and 8 will give rise to a considerably higher frequency than that afforded by the two anodes of the conventional split anode magnetron having juxtaposed anodes defining a cylindrical space charge region about a cathode, each anode being attached to one member of a transmission line similar to that shown.

Referring now to Figs. 4 and 5, there is shown an alternative embodiment of the invention employing but a single turn to the spiral coil 30 and, in addition to the four anode electrodes 25, 26, 27 and 28, a neutral electrode 29 similar to that shown and broadly claimed in my U. S. Patent No. 2,462,698 issued February 22, 1949, and assigned to the same assignee as the present application. Electrode 29 may be conductively connected to coil 30 as by welding thereto, at the longitudinal mid-point or electrically neutral point 30a thereof. It will be noted here that the anode electrodes 25 through 28 are positioned about the inner periphery of the spiral in the following manner: The electrodes 25 and 28 are positioned 90° along the periphery of the coil 30 from neutral electrode 29, one on either side thereof. Electrodes 26 and 27 are positioned 60° further along the periphery of the coil 30 from electrodes 25 and 27, respectively, thereby leaving 60° between electrodes 26 and 27. As indicated by the drawing, the electrode 26 is conductively connected to a point on the lengthwise half of coil 30 opposite the lengthwise half to which the electrode 25 is connected. Similarly, the electrode 27 is connected to a point on the lengthwise half of coil 30 opposite the lengthwise half to which the electrode 28 is connected. The lengthwise halves referred to are, of course, those on the opposite sides of the point 30a. Similarly to the arrangement of Fig. 3, it will, therefore, be seen that as one proceeds around the periphery of the anode configuration, alternate members of the anode electrodes 25 through 28 may be considered as connected to points which are on a lengthwise half of coil 30 on one side of its lengthwise mid-point 30a, while the members of the anode electrodes intermediate between those alternate ones may be considered as connected to point on the other lengthwise half of coil 30 on the other side of its lengthwise mid-point 30a. If, therefore, one lengthwise half of the coil becomes electrically positive and the other negative at any instant during high frequency oscillation of the tank circuit comprising the transmission line, then the electrodes 25 through 28 will be alternatively positive and negative. The five gaps formed between electrodes 25 through 29 occupy the same relative positions and have high frequency fields in the same directions as would be found in five consecutive gaps of a six gap magnetron. The neutral electrode 29 will have no high frequency potential variations imposed upon it because it is connected to a point on the transmission line which has zero high frequency voltage during oscillation such as a nodal point of the standing potential wave in the transmission line. Thus, in accordance with the principles set forth in the aforementioned prior application, its sole function will be to maintain the unidirectional radial electric field through the entire 360° surrounding the cathode necessary for the establishment and maintenance of the rotating magnetron space charge around the cathode. As set forth in the aforementioned application, its use will serve to afford the higher frequency operation characteristic of multi anode constructions with a fewer number of anodes and consequent structural simplicity.

In Fig. 4, the cathode is shown as comprising a straight metallic wire, for example tungsten, although it may be of the construction shown in Fig. 2. As with the coil 9 of Fig. 2, it may be coated with a suitable thermionically emissive coating or left bare of coating as desired.

From the foregoing description it is apparent that magnetrons embodying my invention provide a multianode construction which is very simple to fabricate. At the same time it is simple to operate, principally because it may readily be tuned in the same manner as conventional magnetrons of split anode type by simple means external to the envelope. I have found that these magnetrons also possess to a high degree the advantages of the resonant anode type with respect to higher operating frequencies for a given magnetic field and this without the resonant anode type's objectionable characteristic of a plurality of modes of oscillation of closely related frequency. In my foregoing construction the possible modes of oscillation are sufficiently widely separated in frequency as to obviate the necessity of strapping arrangements used with the resonant anode type. Moreover, there is a substantial improvement in efficiency of operation by comparison with magnetrons of the split anode type and at the same time a substantial decrease in the objectionable backheating of the cathode which has heretofore been one of the objectionable features of the split anode type.

It will be understood that while I have illustrated the invention by means of embodiments employing specific numbers of anodes and spiral turns, the principles of the invention contemplate broadly any number of anodes and spiral turns desired depending upon the frequency and power characteristics sought. In general, it may be stated that where higher frequencies are desired, a higher number of anodes should be used. As an example, I have built and successfully tested magnetrons of the foregoing type operative in the frequency range above 700 megacycles in which six anodes have been used. In one case a two-turn coil having six anodes was successfully operated in the frequency range from 700 to 1100 megacycles with one kilowatt of power output and efficiencies ranging from 65 to 75 per cent depending upon the particular frequency of operation within that range. In another case a one and a half turn coil with six anodes was successfully operated under substantially the same conditions.

It will also be understood that while I have illustrated the invention particularly in connection with magnetrons employed as oscillators, its principles are equally applicable to magnetrons employed for any other functions which magnetron devices are capable of performing, such as those of an amplifier or reactance devices.

Moreover, it will be obvious to those skilled in the art that various 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 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 electrical discharge device of the magnetron type comprising a spiral coil constituting a portion of a resonant circuit, a cathode positioned within said spiral coil, and a plurality of electrodes positioned adjacent to the inner periphery of said spiral coil, each of said electrodes

being conductively connected to a different point on said spiral coil.

2. An electrical discharge device of the magnetron type comprising a spiral coil constituting a portion of a resonant circuit, a cathode positioned centrally within said spiral coil, and a plurality of electrodes positioned adjacent to the inner periphery of said spiral coil in generally cylindrical configuration about said cathode, each of said electrodes being conductively connected to a different point on said spiral coil.

3. An electrical discharge device of the magnetron type comprising a spiral coil constituting a portion of a resonant circuit, a cathode positioned within said spiral coil, and a plurality of electrodes positioned adjacent to the inner periphery of said spiral coil, each of said electrodes being conductively supported from a different point on said spiral coil.

4. An electrical discharge device of the magnetron type comprising a spiral coil constituting a portion of a resonant circuit, a cathode positioned centrally within said spiral coil, and a plurality of anodes positioned adjacent to the inner periphery of said spiral coil in generally cylindrical configuration about said cathode, each of said anodes being conductively supported from a different point on said spiral coil.

5. An electrical discharge device of the magnetron type comprising an envelope, a transmission line including a pair of conductors extending through a wall of said envelope and a spiral coil within said envelope having ends conductively connected each to one of said conductors, a cathode positioned within said spiral coil, and a plurality of anodes positioned adjacent to the inner periphery of said spiral coil, each of said anodes being conductively connected to a different point on said spiral.

6. An electrical discharge device of the magnetron type comprising an envelope, a transmission line including a pair of conductors extending through a wall of said envelope and a spiral coil within said envelope having ends conductively connected each to one of said conductors, a cathode positioned within said spiral coil, and a plurality of anodes positioned adjacent to the inner periphery of said spiral coil in generally cylindrical configuration about said cathode, each of said anodes being conductively connected to a different point on said spiral coil.

7. An electrical discharge device of the magnetron type comprising a spiral coil constituting a portion of a resonant circuit, a cathode positioned within said spiral coil, and a plurality of electrodes positioned adjacent to the inner periphery of said spiral coil, each of said anodes being conductively connected to a different point on said spiral coil, alternate anodes being connected lengthwise of said spiral coil to points on one side of the longitudinal mid-point thereof and the anodes intermediate between said alternate anodes being connected lengthwise of said spiral coil to points on the other side of said mid-point.

8. An electrical discharge device of the magnetron type comprising a spiral coil constituting a portion of a resonant circuit, a cathode positioned within said spiral coil, and a plurality of electrodes positioned in uniform angular distribution around and adjacent to the inner periphery of said spiral coil, alternate members of said electrodes being conductively connected longitudinally of said spiral coil to different points on one side of the longitudinal mid-point thereof, and the intermediate electrodes between said alternate members being conductively connected longitudinally of said spiral coil to different points on the other side of said mid-point.

9. An electrical discharge device of the magnetron type comprising a spiral coil constituting at least a portion of a resonant circuit, a cathode positioned within said spiral coil, and a plurality of anodes positioned adjacent to the inner periphery of said spiral coil, each of said anodes being conductively connected to a different point on said spiral coil, alternate anodes being connected lengthwise of said spiral coil to points on one side of the longitudinal mid-point thereof and the anodes intermediate between said alternate anodes being connected lengthwise of said spiral coil to points on the other side of said mid-point, said points being distributed about said periphery symmetrically with respect to said mid-point.

10. An electrical discharge device of the magnetron type comprising a spiral coil constituting at least a portion of a resonant circuit, a cathode positioned within said spiral coil, and a plurality of anodes conductively supported from and positioned adjacent to the inner periphery of said spiral coil, each of said anodes being supported at a different point on said spiral coil, alternate anodes being supported lengthwise of said spiral coil at points on one side of the longitudinal mid-point thereof and the anodes intermediate between said alternate anodes being supported lengthwise of said spiral coil at points on the other side of said mid-point, said points being distributed about said periphery symmetrically with respect to said mid-point.

11. An electrical discharge device of the magnetron type comprising an envelope, a transmission line including a pair of conductors extending through a wall of said envelope and a spiral coil within said envelope having ends conductively connected each to one of said conductors whereby said spiral coil constitutes a closed conductive extension of said conductors, a cathode positioned within said spiral coil, and a plurality of anodes positioned adjacent to the inner periphery of said spiral coil, each of said anodes being conductively connected to a different point on said spiral coil, said conductors and said spiral coil being formed of a continuous length of hollow tubing whereby a coolant may be circulated therethrough.

12. An electrical discharge device of the magnetron type comprising an envelope, a transmission line including a pair of conductors extending through a wall of said envelope and a spiral coil within said envelope having ends conductively connected each to one of said conductors whereby said spiral coil constitutes a closed conductive extension of said conductors, a cathode positioned centrally within said spiral coil, and a plurality of anodes positioned adjacent to the inner periphery of said spiral in generally cylindrical configuration about said cathode, each of said anodes being conductively connected to a different point on said spiral coil, said conductors and said spiral coil being formed of a continuous length of hollow tubing whereby a coolant may be circulated therethrough.

13. An electrical discharge device of the magnetron type comprising an envelope, a spiral coil within said envelope constituting a portion of a resonant circuit, a cathode positioned within said spiral coil, and a plurality of electrodes positioned adjacent to the inner periphery of said

spiral coil, one of said electrodes being conductively connected to the longitudinal mid-point of said spiral coil, alternate electrodes from said one electrode being conductively connected longitudinally of said spiral coil to points on one side of said mid-point, and the intermediate electrodes between said alternate electrodes being conductively connected longitudinally of said spiral coil to points on the other side of said mid-point.

14. An electrical discharge device of the magnetron type comprising an envelope, a transmission line including a pair of conductors extending through a wall of said envelope and a spiral coil within said envelope having ends conductively connected each to one of said conductors, a cathode positioned centrally within said spiral coil, and a plurality of anodes positioned adjacent to the inner periphery of said spiral coil, each of said anodes being conductively connected to a different point on said spiral coil, alternate anodes being connected to points on one side of the longitudinal mid-point of said spiral coil and the anodes intermediate said alternate anodes being connected to points on the other side of said mid-point.

15. An electrical discharge device of the magnetron type comprising an envelope, a transmission line including a pair of conductors extending through a wall of said envelope and a spiral coil within said envelope having ends conductively connected each to one of said conductors, a cathode positioned along the axis of said spiral coil, and a plurality of anodes positioned adjacent to the inner periphery of said spiral coil in generally cylindrical configuration about said cathode, each of said anodes being conductively connected to a different point on said spiral coil, alternate anodes being connected to points on one side of the longitudinal mid-point of said spiral coil and the anodes intermediate said alternate anodes being connected to points on the other side of said mid-point.

16. An electrical discharge device of the magnetron type comprising an envelope, a transmission line including a pair of conductors extending through a wall of said envelope and a spiral coil within said envelope having ends conductively connected each to one of said conductors whereby said spiral coil constitutes a closed conductive extension of said conductors, a cathode positioned centrally within said spiral coil, and a plurality of anodes positioned in uniform angular distribution around and adjacent to the inner periphery of said spiral coil, alternate members of said anodes being conductively connected to different points on one side of the longitudinal mid-point of said coil, and the intermediate anodes between said alternate members being conductively connected to different points of the other side of said mid-point.

17. An electrical discharge device of the magnetron type comprising an envelope, a transmission line including a pair of conductors extending through a wall of said envelope and a spiral coil within said envelope having ends conductively connected each to one of said conductors whereby said spiral coil constitutes a closed conductive extension of said conductors, a cathode positioned along the axis of said spiral coil, and an odd numbered plurality of anodes positioned adjacent to the inner surface of said spiral coil in generally cylindrical configuration about said cathode, one of said anodes being conductively connected to the longitudinal mid-point on said spiral coil, alternate anodes from said one anode being conductively connected to said points on one side of the mid-point of said coil, and the intermediate anodes between said alternate anodes being conductively connected to points on the other side of said mid-point.

18. An electrical discharge device of the magnetron type comprising a spiral coil constituting a resonant circuit, a cathode positioned within said spiral coil, and a plurality of electrodes positioned adjacent to the inner periphery of said spiral coil, each of said electrodes being conductively connected to a different point on said spiral coil.

19. An electrical discharge device of the magnetron type comprising an envelope, a coil within said envelope constituting a resonant circuit, a cathode positioned within said coil, and a plurality of electrodes positioned adjacent to the inner periphery of said spiral coil, one of said electrodes being conductively connected to the longitudinal mid-point of said coil, alternate electrodes from said one electrode being conductively connected longitudinally of said coil to points on one side of said mid-point, and the intermediate electrodes between said alternate electrodes being conductively connected longitudinally of said spiral coil to points on the other side of said mid-point.

DONALD A. WILBUR.

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