Sept. 2, 1952 J. F. HULL 2,609,522

MAGNETRON

Filed April 3, 1950 4 Sheets-Sheet 1

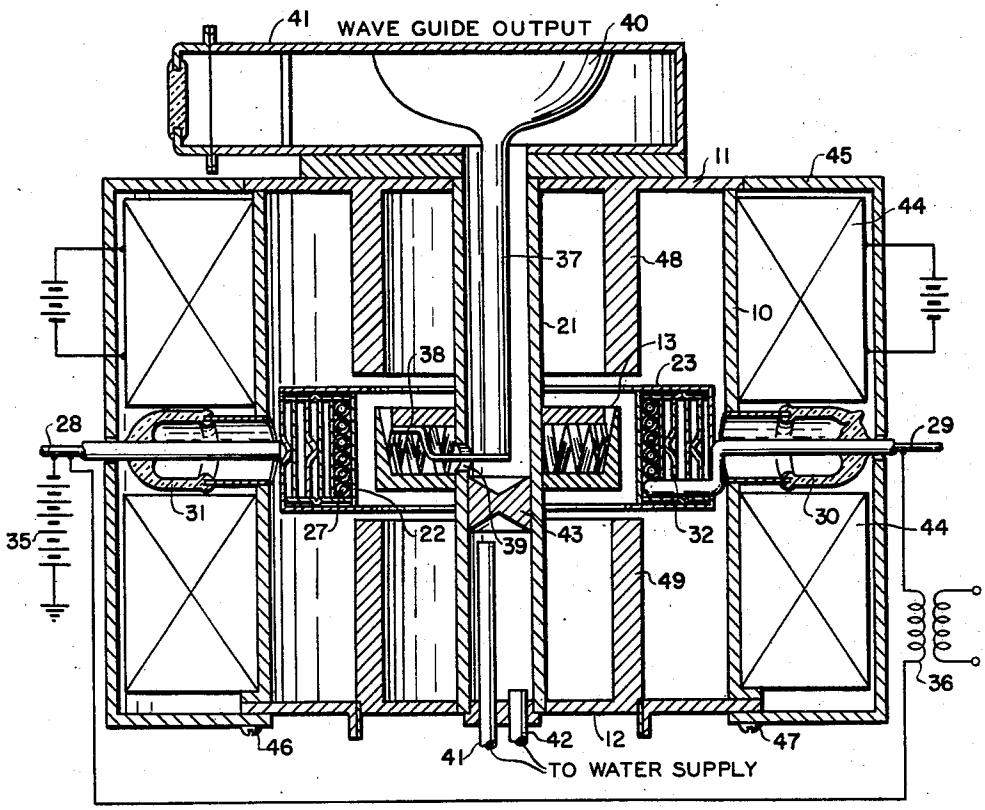


FIG. 1

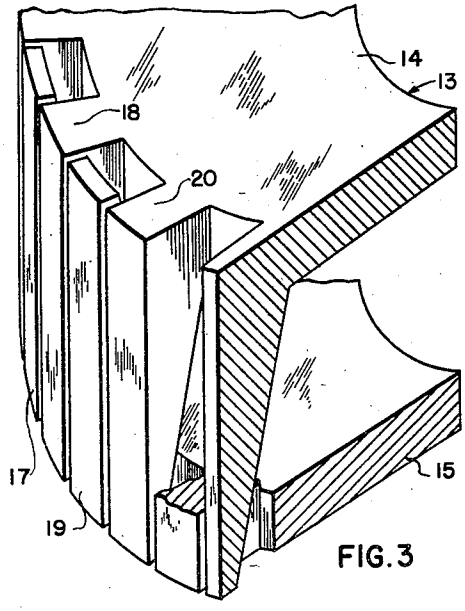


FIG. 3

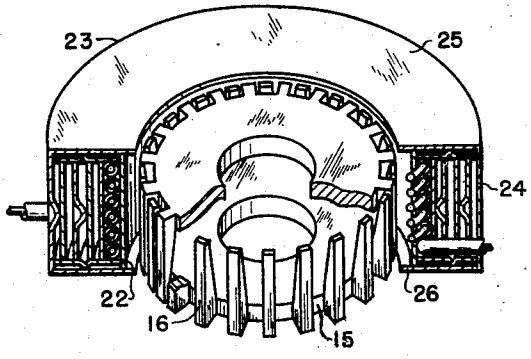


FIG. 2

INVENTOR.
JOSEPH F. HULL

BY
Harry M. Saragovitz
Attorney

Sept. 2, 1952 J. F. HULL 2,609,522

MAGNETRON

Filed April 3, 1950 4 Sheets-Sheet 2

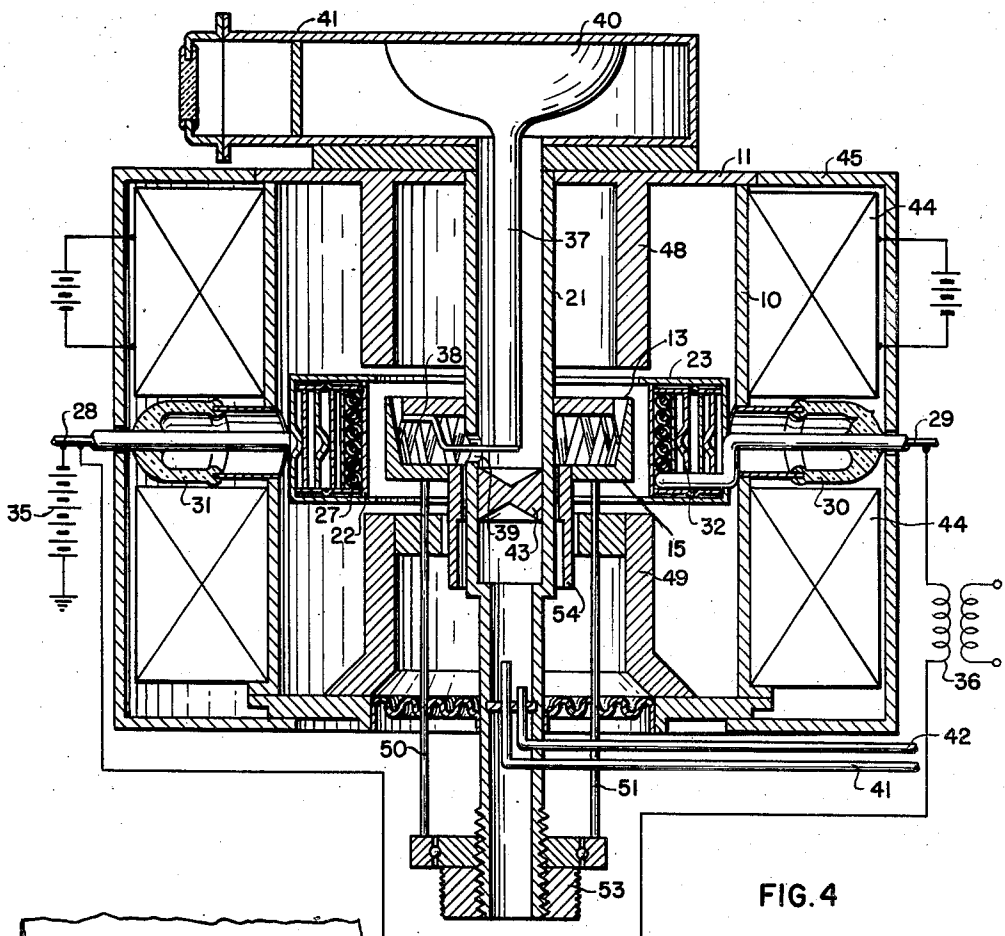


FIG. 4

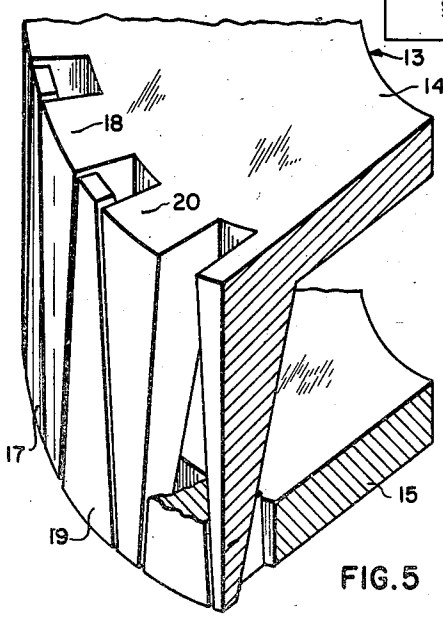


FIG. 5

INVENTOR.
JOSEPH F. HULL

BY
Harry M. Saragovitz
Attorney

Sept. 2, 1952 J. F. HULL 2,609,522

MAGNETRON

Filed April 3, 1950 4 Sheets-Sheet 3

FIG. 7

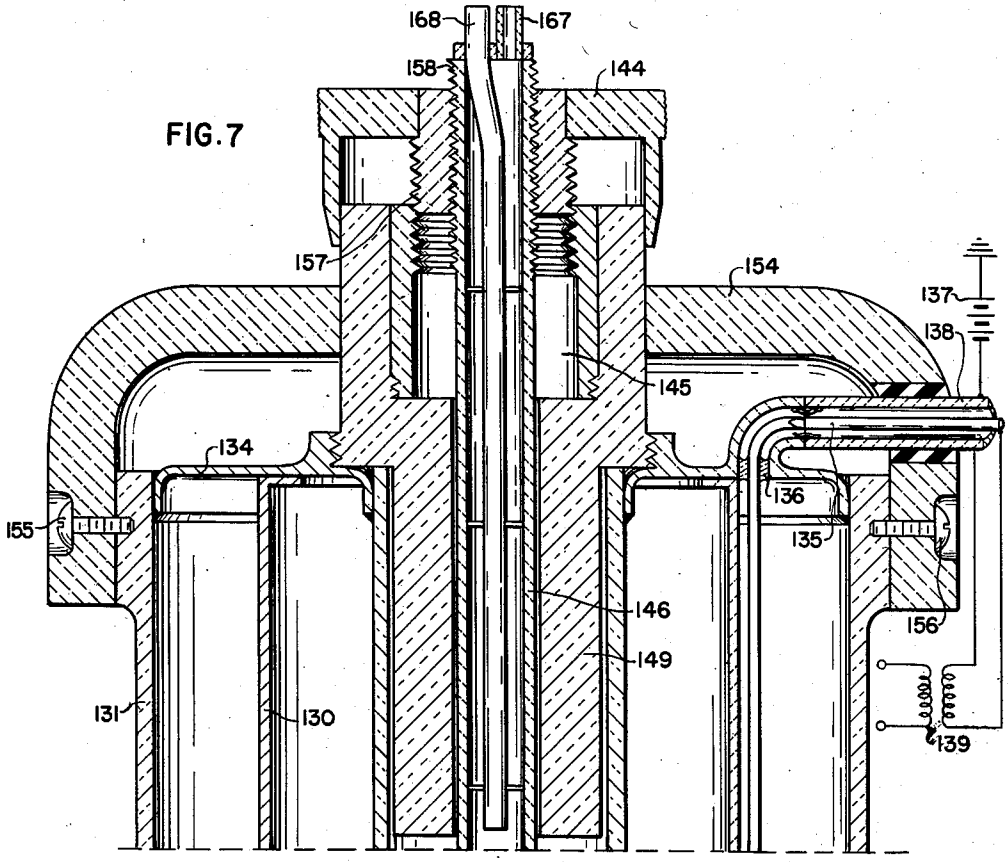


FIG. 9

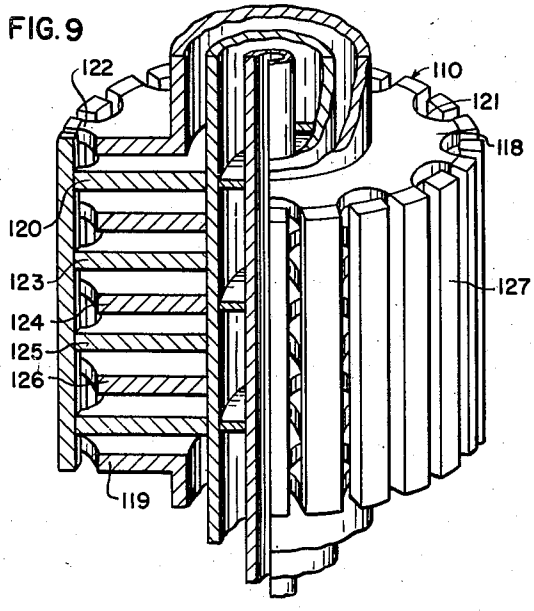
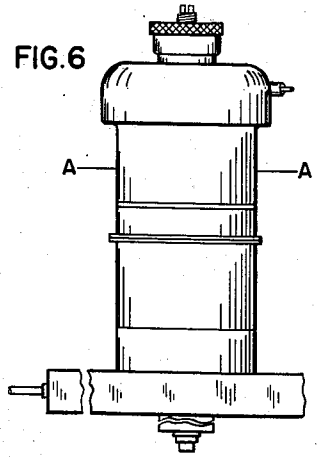


FIG. 6



INVENTOR.
JOSEPH F. HULL

BY
Harry M. Saragovitz
Attorney

Sept. 2, 1952 J. F. HULL 2,609,522

MAGNETRON

Filed April 3, 1950 4 Sheets-Sheet 4

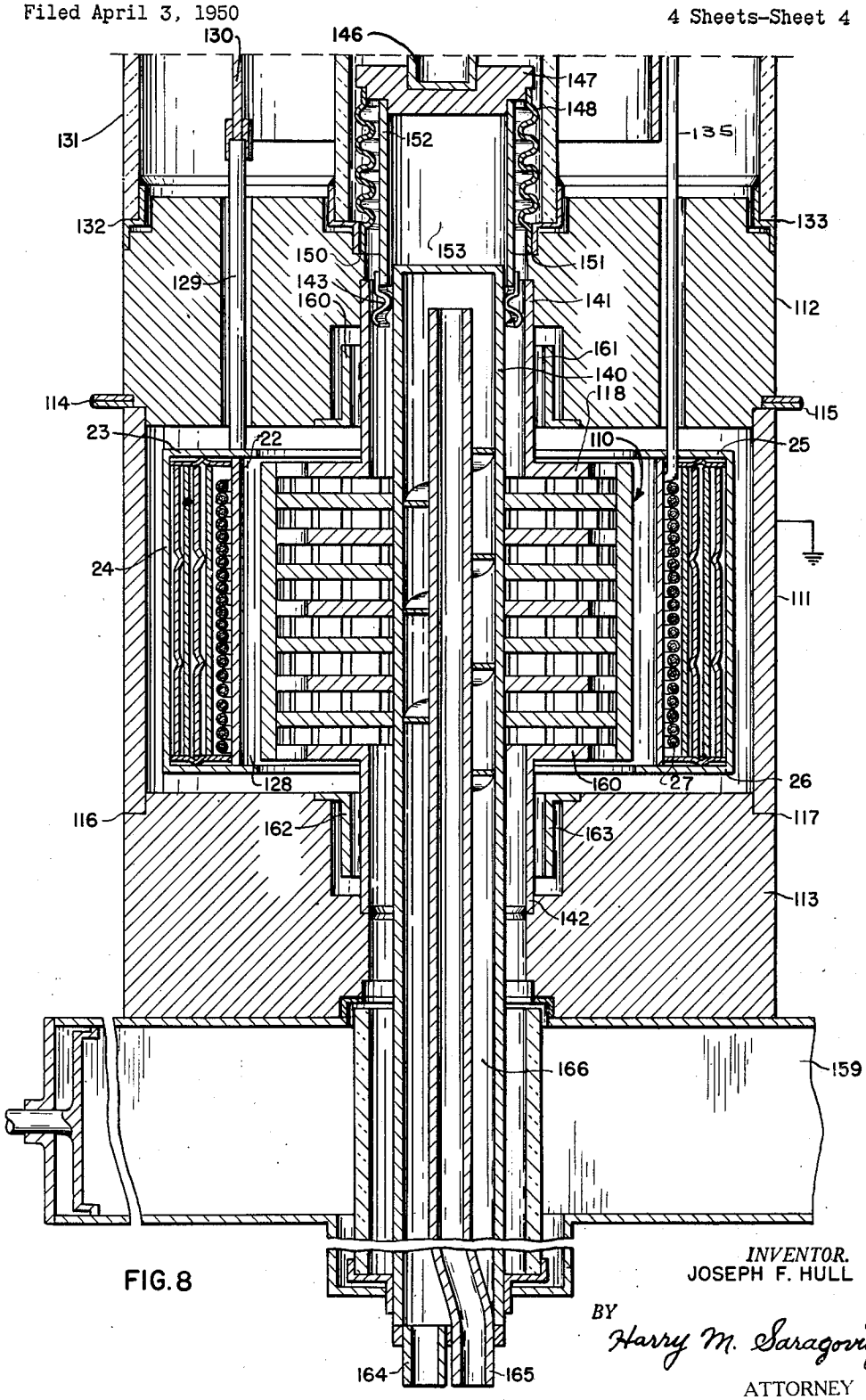


FIG. 8

INVENTOR.
JOSEPH F. HULL

BY Harry M. Saragovitz

ATTORNEY

Patented Sept. 2, 1952

2,609,522

UNITED STATES PATENT OFFICE

2,609,522

MAGNETRON

Joseph F. Hull, Neptune, N. J.

Application April 3, 1950, Serial No. 153,682

5 Claims. (Cl. 315—40)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

1

This is the parent application of divisional application Serial No. 269,572, filed January 31, 1952.

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

This invention relates to electronic devices and more particularly to magnetrons.

In the Patent 2,454,337 which was issued to E. C. Okress on November 23, 1948, there is shown a magnetron structure employing an inverted hole-and-slot type anode structure girdled by a cathode. In this type of structure a number of electrical modes exist which are close together. Thus, such a device will tend to operate in the several different modes which results in reduced efficiency from this type of magnetron structure. In the conventional non-inverted wave or hole-and-slot type of magnetron, mode frequency separation is accomplished by employing so-called straps which connect alternate anode segments. However, the effectiveness of strapping is greatest for the shortest strap length. Inasmuch as the magnetron anode shown in the Okress patent is inverted from the hole-and-slot anode structure of the conventional magnetron, the distance between alternate segments is too great for strapping to be effective and sufficient mode separation is difficult to achieve. If few cavities are used, the cavity structure is so divergent that the high current portion of the cavity occupies too small an area, thus decreasing circuit efficiency. If the number of cavities is large, the number of modes is increased, and as a result there is insufficient mode frequency separation. Due to the fact that the interdigital magnetron is a single cavity resonator and the wave type magnetron is a multi-cavity resonator, it is easy to show why the interdigital magnetron anode structure can be inverted without detrimental effects on mode separation and circuit efficiency. This is not true for the wave type magnetron. Moreover, with the inverted interdigital magnetron, a large diameter cavity can be built with a large number of segments to provide a greater area for the high current flow, and still provide sufficient mode separation.

It is therefore an object of this invention to provide an improved ultra-high frequency electric discharge device of the magnetron type.

Another object of the invention is to provide a magnetron structure wherein the resonant system permits a great degree of mode separation thus increasing the efficiency of the magnetron structure.

2

Still another object of the invention is to provide an inverted magnetron structure employing an interdigital type anode.

Further objects of the invention will appear to those skilled in the art to which it pertains, both by direct recitation thereof as the description proceeds and by implication from the context.

Referring to the accompanying drawings in which like reference numerals indicate similar parts throughout the several views:

Fig. 1 is a cross-sectional view of a magnetron embodying the present invention;

Fig. 2 is a perspective view showing the detailed construction of the magnetron cathode and anode illustrated in Fig. 1;

Fig. 3 is a perspective view showing the detailed construction of the magnetron anode shown in Figs. 1 and 2;

Fig. 4 is a cross-sectional view of a tunable magnetron embodying the present invention;

Fig. 5 is a perspective view of another embodiment of the anode shown in Fig. 3;

Fig. 6 is an elevational view of a tunable magnetron employing a preferred embodiment of the magnetron anode;

Fig. 7 is a vertical cross-sectional view on an axial plane of the portion above line A—A of the magnetron shown in Fig. 6;

Fig. 8 is a vertical cross-sectional view on an axial plane of the portion below line A—A of the magnetron shown in Fig. 7; and

Fig. 9 is a perspective view showing the detailed construction of a preferred embodiment of the anode employed in the magnetron shown in Figs. 6, 7 and 8.

Referring now to Fig. 1 of the accompanying drawing, there is shown an inverted ultra-high frequency magnetron including a copper cylindrical casing or tube 10 with top and bottom end plates 11 and 12 which are welded or otherwise hermetically sealed to the inner surface of said cylindrical casing.

At approximately the central portion of said tube there is provided an anode structure 13 which is shown in perspective detail in Figs. 2 and 3. Anode structure 13, which may preferably consist of copper, may be considered as comprising a pair of spaced annular top and bottom discs 14 and 15, which are axially aligned, and a plurality of oppositely placed sets of uniformly spaced bars 16 extending toward each other from the outer periphery of said discs. Uniformly spaced bars 16 are circumferentially arranged around the outer periphery of said discs in a plane perpendicular to the surfaces thereof so

as to interleave with each other. Each of these bars are of uniform length and width, the length of the bars being approximately equal to the spacing between said discs. Alternate bars such as 17 and 19 are joined to bottom disc 15 while the remaining alternate bars such as 18 and 20 are joined to top disc 14, so that if one goes around the anode structure in any one direction, alternate bars are joined to the same disc. These bars may be of uniform thickness but in order to achieve greater heat dissipation and higher frequency operation, these bars are tapered linearly in such a manner so that each bar is thicker at the joined end than at the opposite end thereof.

In order to support the anode structure centrally with respect to the tube, the inner periphery of annular anode discs 14 and 15 are brazed to the outside surface of tubular member 21, made of copper or other non-magnetic metal, which extends longitudinally from top end plate 11 to bottom end plate 12 through the center of the tube and is coaxial therewith. The region bounded by top and bottom discs 14 and 15, the portion of the outside surface of tubular member 21 therebetween and the interleaved bars is termed the magnetron resonant chamber.

Girdling and radially spaced from said bars is cathode 22 which is coated with an emissive material and which is held in position by channel housing 23. Said channel housing consists of lateral cylindrical wall 24 and top and bottom end discs 25 and 26. The inner periphery of top and bottom end discs 25 and 26 of said housing extend radially inward slightly beyond the circumferential emitting surface of cathode 22, as shown in Fig. 2, in order to provide cathode end shields, thus preventing electron leakage from the interaction space between bars 16 and cathode 22.

Within said channel housing and juxtaposed with said cathode there is provided a heater coil 27, one end of which is welded to channel housing 23. The other end of coil 27 is insulated from channel housing 23 and is connected to end conductor 29 which extends through lateral wall structure of casing 10, and is supported coaxially in glass seal 30. Cylindrical heat shields 32 are provided within channel housing 23 between cylindrical wall 24 and heater coil 27. End conductor 28 which is welded to channel housing 23 also extends through lateral structure of casing 10 and is supported coaxially in glass seal 31. The direct-current high potential 35 is applied in the usual manner through end conductor 28 and alternating-current heater coil potential 36 is supplied between end conductors 28 and 29 to supply the heater current.

Within tubular member 21 and coaxially therewith is an inner conductor 37 which extends approximately half the length of the upper portion of said tubular member. A coupling loop 38 is located within the resonant chamber and has a stem extending radially inward through a hole 39 in tubular member 21, and connects with the lower end of inner conductor 37. Thus, effectively, tubular member 21 and inner conductor 37 comprise a coaxial output line for the magnetron. Door knob coupler 40 connects with the upper end of inner conductor 37 in order to couple radio frequency energy to output waveguide 41.

Water or other liquid cooling of the anode structure may be effected by the provision of rigid inlet and drain pipes 41 and 42, respectively, which are arranged within the lower portion of tubular member 21 as shown. Water stopper plug 43 is positioned within tubular member 21 between the lower end of inner conductor 37 and the upper end of inlet pipe 41 in order to prevent fluid from entering into the resonant cavity. Water flows continuously through inlet pipe 41 and the overflow is removed through drain pipe 42. Thus, at all times a jacket of water is provided in the lower portion of tubular member 21 between plug 43 and drain pipe 42 to dissipate the heat generated in anode structure 13.

In order to provide a uniform magnetic field, the magnetron of the present showing is provided with ring-like magnetic coils 44 which are conveniently situated exterior to casing 10. Girdling and radially spaced from the outer periphery of said coils is a cylindrical iron casing 45 which is joined to bottom end plate 12 of tube 10 by means of studs 46 and 47. Holes are provided in said iron shell to provide convenient access to end conductors 28 and 29.

In order to provide radio frequency chokes to further decrease the leakage of electromagnetic energy from the resonant chamber, there are provided a pair of cylindrical iron sleeves 48 and 49 which depend from the inner periphery of top and bottom end plates 11 and 12, respectively. Said sleeves respectively girdle the upper and lower portion of tubular member 21 and are coaxial therewith, and extend inwardly from both top and bottom members toward the anode for a distance approximately ¼ wave length of the operating frequency. The outer diameter of said sleeves are approximately equal to twice the diameter of the tubular member 21.

That portion of the top and bottom end plates 11 and 12 between the sleeves and tubular member 21 is composed of copper or any other suitable non-magnetic material, while the remainder of the top and bottom end plates is composed of iron. In this manner, the magnetomotive force is applied close to the region of the interaction space in order to minimize magnetic flux leakage. Thus, a uniform magnetic field is effectively applied to the interaction space in the proximity of anode 13.

The combined influence of the uniform magnetic field established by the coils 44 over the interaction space, the direct current electrical field due to the voltage applied between anode 13 and cathode 22 and the potential due to the space charge cloud of the electrons, cause the electrons emitted from cathode 22 to migrate between said cathode and anode in a circumferential path coaxial with the anode. Simultaneously, as the electrons are rotating, the anode segments are individually assuming a sinusoidal time varying potential such that each anode segment is 180 electrical degrees out of time phase with each adjacent segment. If the rotational velocities of the electrons are such that any one individual electron is always under a positive segment, synchronization is said to occur, that is, the electrons are keeping step with the electric field of the anode structure. It is well known that when said synchronization occurs, magnetron oscillations may be generated provided voltage and magnetic field are of proper value for the particular mode of operation which in the present instance is the one known in the art as the π mode.

In Fig. 4 there is shown a magnetron employing an anode 13 which differs from the anode

shown in Fig. 3, only in that bottom anode disc 15 is axially movable for tuning the magnetron. The means for axially moving disc 15 consists of two rods 50 and 51 which extend through sleeve 49 and sealing bellows 52 to ball bearing knurled nut 53. Cylindrical choke 54 is provided to prevent leakage of electromagnetic energy from the interaction space. As shown in Fig. 5, the interleaved bars of anode 13, in addition to being tapered as shown in Fig. 3, may also be circumferentially tapered so that the teeth are wider at the joined ends than at the opposite ends thereof in order to achieve a wider tuning range.

Figs. 6, 7 and 8 illustrate a tunable magnetron employing a preferred modification of the anode structure which is shown in detail in Fig. 9.

The tunable magnetron shown in Figs. 6, 7 and 8 includes an anode structure 110 which is axially mounted within non-magnetic metallic shell 111, this shell being welded to upper pole piece 112 as well as lower pole piece 113, as illustrated at 114, 115, 116 and 117 respectively. As shown in Fig. 9, anode structure 110 consists of a plurality of axially aligned annular discs having uniform outer diameters which are stacked one above the other and are equi-distantly spaced from each other. With the exception of upper and lower anode end discs 118 and 119, the inner diameter of the intermediate anode annular discs such as 120, 123 and 126 are also uniform. Circular shaped cut-outs 121 are circumferentially and uniformly spaced around the outer periphery of each of said discs, thus providing uniformly spaced teeth 122. Said discs are positioned one above the other so that the teeth of only alternate discs such as 123 and 125 and 124 and 126 are coplanar. As illustrated, bars 127 are in abutment with said coplanar teeth, one bar for each vertical row of coplanar teeth. Each of these bars are of uniform length, width and thickness, the length of the bars being substantially equal to the spacing between upper and lower anode end discs 118 and 119.

Girdling and radially spaced from bars 127 is a cathode 22 which is coated with an emissive material on its inner surface and which is held in position by channel housing 23, said housing consisting of lateral outer cylindrical wall 24 and top and bottom end discs 25 and 26. The inner periphery of top and bottom end discs 25 and 26 of said housing extend slightly beyond the circumferential emitting surface of cathode 22 in order to provide cathode end shields, thus preventing electron leakage from the interaction or discharge space 128 of the magnetron between coplanar bars 127 and said cathode.

Channel housing 23 is rigidly held in place by three supporting rods, one of which is illustrated at 129, one end of each of said rods being welded to disc 25 and the other end being welded or brazed to inner metal casing 130 which is encompassed by outer ceramic shell 131. Said shell is brazed to upper pole piece 112 as illustrated at 132 and 133. Both the inner casing 130 and the outer ceramic shell are hermetically sealed by annular cap 134.

Within said channel housing and juxtaposed with cathode 22 there is provided an insulated heater coil 27, one end of which is welded to channel housing 23. The other end of coil 27 is insulated from channel housing 23 and connected to end conductor 135 which extends through hole in cap 134 and is supported coaxially therein by glass seal 136. The direct-current high potential 137 is applied in the usual manner through end cylindrical conductor 138 and alternating-current heater coil potential 139 is supplied between end conductors 135 and 136 to supply heater current.

In order to support anode structure 110 centrally with respect to cathode 22 and shell 111, the inner diameters of all the stacked annular discs, with the exception of upper and lower anode end discs 118 and 119, are brazed to the outside surface of cylindrical casing 140 which is coaxial and concentric with shell 111. The inner diameters of anode end discs 118 and 119 are slightly larger than the inner diameters of the intermediate annular discs. Tubular members 141 and 142 are brazed to the inner diameters of end discs 118 and 119, respectively, said tubular members being concentric and coaxial with cylindrical casing 140. Tubular members 141 and 142 will hereinafter be referred to as the upper tubular member and as the lower tubular member, respectively. Thus, effectively, upper and lower tubular members 141 and 142 are the outer conductors of a coaxial line, the inner conductor of which consists of the outer surface of cylindrical casing 140.

Positioned between the inner wall of upper tubular member 141 and the outer wall of cylindrical member 140 is a cylindrical sliding contact 143 which is adjustable for tuning the magnetron. Sliding contact 143 effectively is a short circuit for the coaxial line which includes upper tubular member 141. The tuning mechanism includes tuning knob 144, a non-magnetic driving screw 145, a shaft 146, the lower end of which terminates in the upper end of movable cylindrical flange 147 and is welded thereto, and metal bellows 148. Tuning shaft 146 is insulated from annular cap 134 and is centrally positioned by ceramic insulator 149 which is concentric and coaxial with inner casing 130 and outer shell 131.

The upper end of bellows 148 is brazed to the lower end of movable flange 147 while the lower end of the bellows is brazed to upper pole piece 112 at 150 and 151, respectively. Sliding contact 143 is supported in position by tubular member 152, the upper end of which is welded to movable flange 148. Well 153 is proportioned so as to allow the desired degree of vertical travel of sliding contact 143.

The tuning mechanism is centrally positioned by ceramic mounting yoke 154 which is attached to outer ceramic shell 131 by studs 155 and 156 respectively. Since the non-magnetic screw 145 is fastened to the tuning knob, it either raises or lowers shaft 146 because of the threaded engagements 157 and 158, which are of opposite pitch. When tuning knob is rotated in one direction, it moves downward because of threads 157 and at the same time the tuning shaft moves downward with respect to the tuning knob because of thread 158. Thus, both movements combine to move shaft 146 downwards. Bellows 148, therefore, is lowered, which in turn causes the sliding contact 143 to move down, thus tuning the magnetron. The output of the magnetron is coupled to wave guide 159 from the coaxial line which includes lower tubular member 142.

In order to prevent leakage of electromagnetic energy from the interaction space between bars 127 and cathode 22, cylindrical chokes are provided in the usual manner as illustrated at 160, 161, 162 and 163.

Water or other liquid cooling of the anode structure may be effected by the provision of rigidi nlet pipe 164 and drain pipe 165 which is centrally positioned within cylindrical casing

member 140 and is coaxial therewith. As here shown, the cooling liquid spirally circulates within cylindrical casing 140 along spiral fluid channel 166 and the overflow is removed through drain pipe 165. Thus, at all times a jacket of water is provided to dissipate the heat generated in the anode structure. Similarly, in order to cool sliding contact 143 water or other cooling liquid is made to circulate within tuning shaft 146 by means of inlet pipe 167 and overflow pipe 168.

While the invention has been described with reference to several particular embodiments, it will be understood that various modifications of the apparatus shown may be made within the scope of the following claims.

What is claimed is:

1. A magnetron comprising a cylindrical housing having top and bottom end plates, an anode, means extending between said top and bottom plates and coaxial with said housing for supporting said anode, said anode comprising axially aligned upper and lower annular discs spaced from each other and having oppositely positioned sets of bars extending toward each other from the outer periphery of said annular discs, the inner periphery of said discs being mounted on said supporting means to centrally position said anode coaxially within said housing, and a cathode girdling said anode and within said housing.

2. A magnetron comprising a cylindrical housing having top and bottom end plates, a longitudinal tubular member disposed concentrically within said housing between said top and bottom plates, an anode including axially aligned upper and lower annular discs spaced from each other and having oppositely positioned sets of bars extending toward each other from the outer periphery of said annular discs, the inner periphery of said discs being mounted on the outer surface of said tubular member to centrally position said anode with respect to said cylindrical housing, a cathode girdling said anode and radially spaced from said bars, and means adjacent said cathode for producing an effective uniform magnetic field in the proximity of said anode.

3. A magnetron device comprising a cylindrical

housing having top and bottom end plates, a tubular member disposed coaxially within said housing between said top and bottom plates, an anode mounted on said tubular member coaxially within said housing, said anode comprising axially aligned upper and lower annular discs spaced from each other, a plurality of bars interleaving with each other, said bars being mounted on the outer periphery of each of said upper and lower discs, and a cathode coaxially around said bars and radially spaced therefrom.

4. A magnetron comprising a cylindrical housing having top and bottom end plates, a longitudinal tubular member disposed coaxially within said housing between said top and bottom plates, an anode comprising axially aligned upper and lower annular discs spaced from each other and having oppositely positioned sets of bars extending toward each other from the outer periphery of said annular discs, the inner periphery of said discs being mounted on the outer surface of said tubular member to centrally position said anode with respect to said cylindrical housing, a cathode girdling said anode and radially spaced from said bars, a cylindrical channel housing supporting said cathode in position with respect to said anode, sleeves of quarter wavelength depth projecting inwardly from each of said end plates coaxially with said tubular member and having an inner diameter greater than said tubular member, and a coaxial output tube positioned within said tubular member and extending through said top end plate.

5. A magnetron in accordance with claim 4 wherein the bars interleave with each other.

JOSEPH F. HULL.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,463,416	Nordsieck	Mar. 1, 1949
2,482,495	Laidig	Sept. 20, 1949
2,501,354	Pease	Mar. 21, 1950
2,522,184	Ludi	Sept. 12, 1950