

Dec. 17, 1946.

E. D. McARTHUR

2,412,824

MAGNETRON

Filed June 22, 1942

2 Sheets-Sheet 1

Fig. 1.

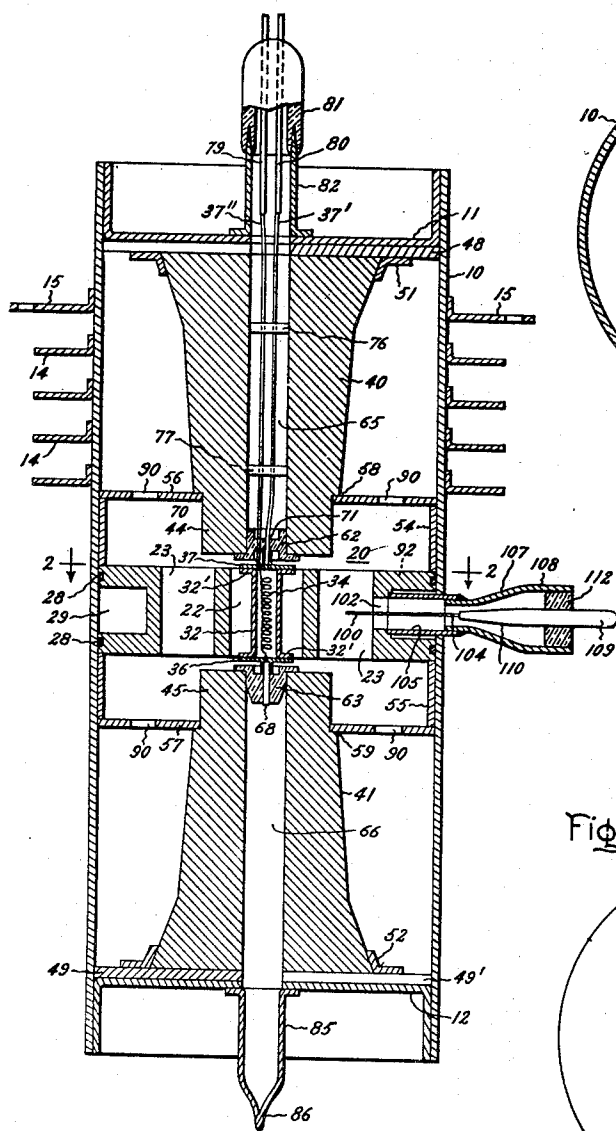


Fig. 2.

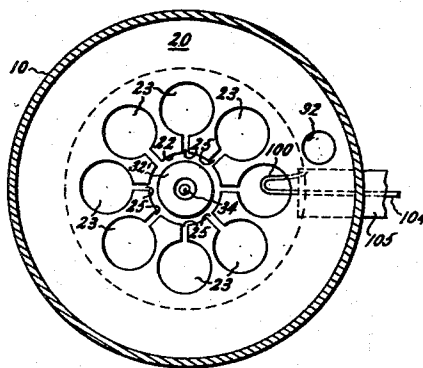


Fig. 3.

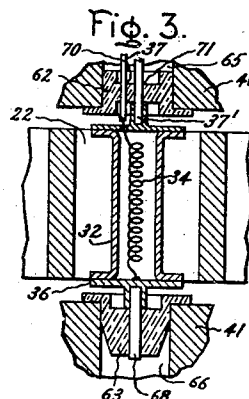
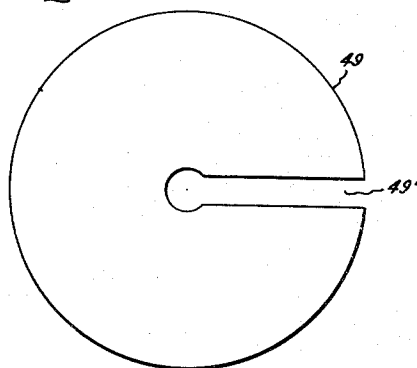


Fig. 4.



Inventor:
Elmer D. McArthur,
by *Harry E. Dunham*
His Attorney.

Dec. 17, 1946.

E. D. McARTHUR

2,412,824

MAGNETRON

Filed June 22, 1942

2 Sheets-Sheet 2

Fig. 5.

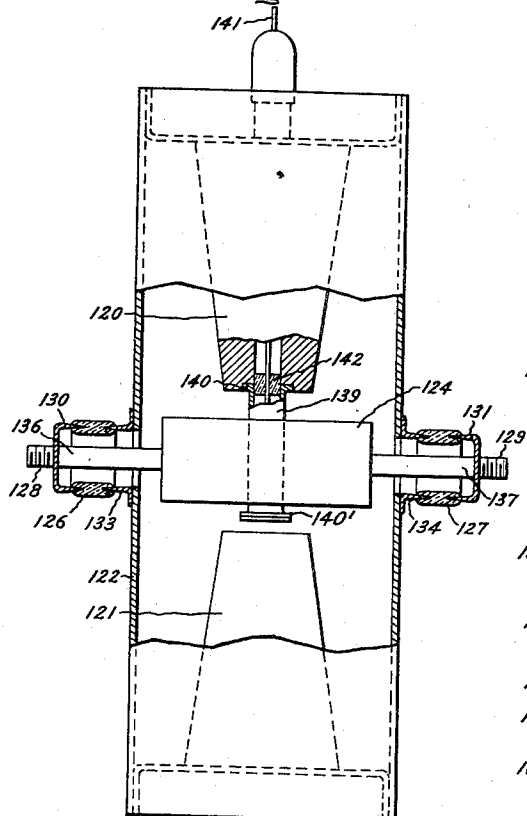


Fig. 6.

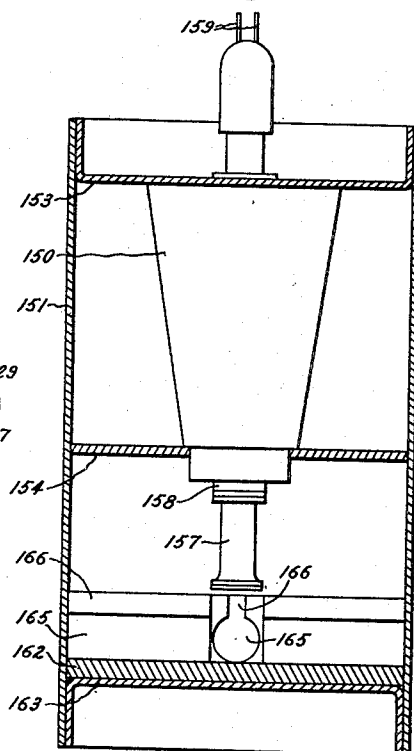
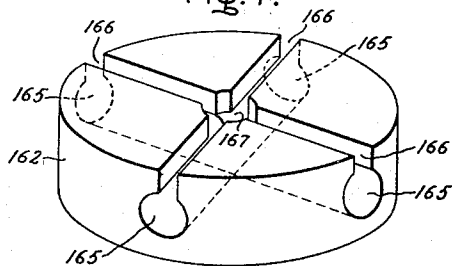


Fig. 7.



Inventor:
Elmer D. McArthur,
by *Harry E. Driskell*
His Attorney.

UNITED STATES PATENT OFFICE

2,412,824

MAGNETRON

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

Application June 22, 1942, Serial No. 447,903

9 Claims. (Cl. 250—27.5)

1

The present invention relates to improvements in high frequency electronic devices of the magnetron type.

As is well-known, the functioning of a magnetron as a generator of high frequency waves depends upon the combined action of appropriately directed electric and magnetic fields upon electrons which move in an interelectrode space. In general, the frequency of the waves which may be developed by such devices is a function of the strength of the magnetic field employed, the required field strength being higher for the higher frequencies. Because of this relationship, magnetrons which are operable in the ultra-high frequency band have heretofore been required to be associated with massive magnetic structures, leading to a cumbersome construction for the apparatus as a whole.

It is a primary object of the present invention to provide an improved type of ultra-high frequency magnetron in which the weight and size of the operative parts, including especially the magnetic elements, are reduced to a minimum. In general this object is realized by the use of a construction in which the magnetic field is produced by permanently magnetized pole pieces located within a container which consists wholly or in part of ferromagnetic components arranged to provide a return path for magnetic flux traversing the pole pieces. In this way, with the electrodes of the device located within the container in appropriate proximity to the pole pieces, it proves possible to obtain intense magnetic fields in the interelectrode space without the use of a separately excited electromagnet or other external appurtenances. The resultant structure is light in weight and has the further advantage that its magnetic components may be adjusted in the factory for best operation with the assurance that no further adjustment will be required in the field.

A further important feature of the improved construction consists in an arrangement by which the current supply wires for the cathode are introduced through the center of one of the magnetic pole pieces in a manner which avoids coupling the cathode circuit to the high frequency fields generated by the operation of the magnetron.

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 drawings in which Fig. 1 is a vertical section of a magnetron device suitably embodying the invention; Fig. 2 is a transverse sectional view serving to illustrate the anode structure employed in the device of Fig. 1; Fig. 3 is an enlarged view in partial sec-

2

tion of the cathode of the device of Fig. 1; Fig. 4 is a detail view of one of the structural elements of the device of Fig. 1; Fig. 5 is a longitudinal section of a modification of the invention; Fig. 6 is a longitudinal section illustrating a further modification, and Fig. 7 is a perspective of one element of the device of Fig. 6.

Referring particularly to Fig. 1 there is shown an elongated cylindrical container, the lateral wall structure of which is provided by a single metal tube 10 consisting of ferromagnetic material such as cold rolled steel or the like. The ends of the container are closed by flanged members 11 and 12 which are welded or otherwise hermetically joined to the inner surface of the part 10. The outer surface of the envelope is provided with a series of circumferentially extending fins 14 which are adapted to serve as heat dissipating elements and a somewhat larger circular element 15 provided near the upper end of the container acts as a mounting flange for the device as a whole. (Any number of additional cooling fins may be used, as required.)

Within the container and approximately at its central region there is provided an anode structure 20 shown in plan view in Fig. 2. This comprises a circular member which has a relatively large central opening 22 and a series of smaller openings 23 arranged symmetrically about the central opening. The central opening is joined to the openings 23 by means of radially extending slots 25.

The structure 20, which preferably consists of copper, is supported by being brazed to the interior wall surface of the part 10. To facilitate the brazing operation, small channels 28 are cut in the outer periphery of the structure and these are used to receive rings of brazing material applied before the anode structure is inserted within the container. A relatively large circumferentially extending channel 29 serves to reduce the overall weight of the structure.

Within the opening 22 of the anode structure there is provided an indirectly heated cathode comprising a sleeve 32 of nickel or other suitable material having flanges 32' spun up at its extremities. This sleeve, which may be coated externally with a suitable activating material such as barium oxide, contains a filamentary heater 34 by which it may be maintained at an emissive temperature. One end of the cathode sleeve is closed by a metal disk 36 while an apertured disk 37 partially closes its other extremity.

In the operation of the device a space charge is assumed to be developed in the space between the cathode sleeve 32 and the surrounding anode structure by the application of a suitable potential impressed between one of the cathode lead-in wires 37' and 37'' and the container 10 to which the anode structure is directly conductively con-

nected. The electrons which compose this space charge are given a spiral or orbital motion by a magnetic field produced by means shortly to be described, and their resultant gyrations about the cathode produce excitation of the anode structure at its resonant frequency. The functioning of the anode structure in the latter connection may be explained from one point of view by considering that it is made up of a plurality of mutually coupled resonant units in each of which inductance is provided by the wall surface bounding one of the circular openings 23 and capacitance is provided by the opposing surface of one of the slots 25. Taking this viewpoint, it will be seen that the operating frequency is in a large measure determined by the dimensions of the openings 23.

For the purpose of providing a magnetic field of sufficient intensity to permit the apparatus to function in its intended fashion, there are provided within the container 10 tapered magnetic pole pieces 40 and 41 which are directed axially of the container and which extend in close proximity to the upper and lower surfaces of the anode structure 20. For present purposes these pole pieces are assumed to be permanently magnetized in such a sense that the north pole of one faces the south pole of the other.

In order to assure the existence of a magnetic field of the required intensity the pole pieces 40 and 41 should be constituted of a magnetizable substance having a high coercive force and a high energy factor. One of the materials which may be used in this connection is that known as Alnico, meaning a particular class of alloys of aluminum, nickel and cobalt. 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. Other magnetic materials which may be employed are alloys of iron, nickel and titanium as described, for example, in Honda Patents 2,105,652 and 2,105,658.

If the pole pieces 40 and 41 are constituted of Alnico, which is considered to be a preferred material, they are normally prepared in cast form and have their critical surfaces finished by grinding. The ground surfaces may include, for example, the end surfaces of both pole pieces and the peripheral surfaces indicated by the numerals 44 and 45 respectively. These latter surfaces, together with the end surfaces which adjoin them may advantageously be copper plated to reduce losses attributable to high frequency circulating currents induced by the proximity of these surfaces to the interelectrode spaces in which high frequency waves are generated.

In order to provide a low reluctance connection between the base extremities of the respective pole pieces and the lateral wall of the container, the pole pieces may be respectively seated upon relatively thick disk-like members 48 and 49 consisting of ferro-magnetic material such as steel. For the purpose of securing the pole pieces fixedly to these basing members, use may be made of clamping rings 51 and 52 slipped over the pole pieces and welded to the basing members. Each basing member is of such diameter as to fit snugly within the tubular container part 10 so as to provide a low reluctance connection with that part, and is welded to one of the closure members 11, 12.

Accurate spacing of the pole pieces 40 and 41 with reference to the anode structure 20 may be obtained by the use of spacing rings 54 and 55 used in the manner indicated. As is shown in

Fig. 1, each of these rings is interposed between one surface of the anode structure and the surface of an apertured disk 56, 57, each disk in turn being in abutment with an appropriately formed shoulder provided on the adjacent pole piece as indicated at 58 and 59. The spacing rings 54 and 55 may be welded in place before the pole pieces are inserted within the container.

With the pole pieces 40 and 41 arranged inside the container 10 it becomes convenient to use the pole pieces as a supporting means for the cathode structure 32. This may be done, for example, by the use of a pair of insulating beads 62 and 63 which are respectively centered in axially extending openings 65 and 66 cut in the pole pieces. The lower bead 63 is provided with a central aperture adapted to receive a centering stud 68 projecting downwardly from the cathode end plate 36. The upper bead 62 has two separate openings 70 and 71 through which the current supply wires 37' and 37'' extend. These wires, which are held in spaced relation within the channel 65 by means of additional insulators 76 and 77, are joined at their extremities to relatively heavy lead-in wires 79 and 80. These in turn are sealed into the container through a glass-to-metal seal which comprises a body of glass 81 fused to the extremity of a metal eyelet 82. This arrangement of the cathode supply leads has the particular advantage that it avoids any substantial coupling between the cathode supply circuit and the high frequency fields generated in the interelectrode space, thus being a consequence of the fact that both the supply leads extend axially with respect to the electrode structures and are fully shielded by the body of the pole piece 40.

In fabricating the construction of Fig. 1 the anode structure 20 is first positioned within the container part 10 and secured in place. Thereafter, the spacing rings 54 and 55 are inserted and finally the pole pieces and their associated basing structures are put in place. The cathode 32 may be preliminarily assembled with the pole piece 40 before that part is lowered into the container. After the closure members 11 and 12 have been welded in, the container may be evacuated through an exhaust tabulation 85, which is then sealed off as indicated at 86.

To permit the evacuation of all parts of the container, it is necessary to provide suitable passageways connecting the various sections of the enclosed space. To this end, the disk-like members 48 and 49 may be provided with radially extending slots such as the slot 49' which is illustrated in Fig. 4 in connection with the part 49. In this way the channel 66 is enabled to communicate with the space outside the pole piece 41 through the channel 49', and a similar connection with reference to the channel 65 is provided by the corresponding slot in the part 48. With the same object in view, openings 90 may be provided in the positioning disks 56 and 57. An opening 92 provided in one surface of the anode structure 20 makes the channel 29 accessible to the evacuating system.

After the container is fully evacuated and sealed off, the pole pieces 40 and 41 may be magnetized in a known manner by being placed in a magnetic field of suitable intensity. It is an advantage of the illustrated construction that for each particular device the degree of magnetization of the pole pieces can be adjusted in the factory to a value which assures the most satisfactory operation of the device as a whole. Since all the parts

5

of the tube structure are fixed and since no external magnetic appurtenances have to be added in the field, installation and use of these tubes is greatly simplified.

When a device such as that illustrated in Fig. 1 is placed in operation, it is, of course, necessary to provide some means for abstracting a portion of the energy developed in the interelectrode space. This may be done in one way by an arrangement which includes a coupling loop 100 introduced through an opening 102 in the wall of the anode structure. The coupling loop in the arrangement shown has an extension in the form of a wire 104 which constitutes the inner conductor of a coaxial transmission line having a tubular part 105 as its outer conductor. The tube 105 passes through the wall of the container cylinder 10 and may be exteriorly connected through a tapering enlargement 107 with a somewhat larger tubular part 108. In similar fashion, the wire 104 is merged into a larger conductor 109 through a tapered transition region 110 which is of such configuration as to avoid any substantial change in the characteristic impedance of the line. (The fulfillment of this latter condition requires the maintenance of a constant ratio between the diameters of the outer and inner conductors.) The conductors 108 and 109 may connect with an antenna or other agency for utilizing the high frequency energy developed by the apparatus, and their size is determined with this end in view. The vacuum tightness of the container is preserved by means of a bead of glass 112 which forms a seal between the conductor 109 and the surrounding tubular member 108.

In an arrangement such as that of Fig. 1 in which the cathode is not at ground potential it is necessary to provide an insulating transformer in connection with the supply of filament heating current. In order to avoid this requirement it is preferable in some instances to employ a structure in which the cathode is grounded to the structure of the enclosure and to adopt provisions for insulating the anode from ground. This possibility is illustrated in Fig. 5.

In the figure last referred to the magnetic structure is of the same general character as that described in connection with Fig. 1 and comprises permanently magnetized pole pieces 120 and 121 which are enclosed within a metallic container 122 consisting of ferromagnetic material. The pole pieces have a low reluctance magnetic connection with the structure of the enclosure so that a return path is provided for the magnetic flux.

The anode structure, which is indicated at 124, is functionally similar to the anode 20 of Fig. 1, being provided internally with a plurality of resonant cavities (not shown) which have a resonant frequency corresponding to the desired frequency of operation of the apparatus. The structure is insulated from the metallic enclosure 122 and from the other parts of the device by means of glass insulators 126 and 127 which serve also as seal-in means for anode terminals 128 and 129. These terminals are associated with cup-like members 130 and 131 which are sealed into the glass rings 126 and 127 respectively, the rings in turn being supported from metal eyelets 133 and 134 secured to the outer surface of the enclosure. Heavy conductive rods 136 and 137 extending between the anode structure 124 and the cap members 130 and 131 afford a rigid support for the anode structure.

Power is assumed to be taken out of the anode

6

structure by means of a coupling loop, which, however, does not appear in the particular view of the structure which is afforded by Fig. 5.

The cathode, which extends centrally through the anode structure 124, comprises an emissive tubular part 139 which terminates in flanges 140 and 140'. A heater (not shown) is arranged within the part 139 and serves to maintain it at emissive temperature. The cathode flange 140 is seated in an appropriately formed recess provided in the lower extremity of the pole piece 120 so that the cathode is electrically grounded to the magnetic structure. A lead-in wire 141 which extends axially through the pole pieces 120 and through an insulating bead 142 at the upper end of the cathode make it possible to supply heating current to the cathode filament, a return path for this current being provided through the grounded structure of the cathode proper.

It is not essential that a magnetron produced in accordance with the invention be symmetrical with respect to a central transverse plane, and the alternative embodiment of Fig. 6 represents a construction in which this condition is not fulfilled. In this case a permanently magnetized pole piece 150 is enclosed within a ferromagnetic container 151 which forms part of the magnetic circuit. The pole piece 150 is based upon a ferromagnetic header 153 which closes the upper end of the container 151 and is partially supported within the container by means of a non-magnetic ring 154. A cathode structure 157 depends centrally from the lower extremity of the pole piece 150, being insulated from the pole structure by means of an interposed insulating element indicated at 158. Potential and heating current are supplied to the cathode through lead-in wires 159.

Below the cathode 157 there is provided a multicavity anode 162 which is shown in perspective detail in Fig. 7. This anode is formed of magnetic material (e. g., iron or steel) so that it serves not only as an anode but also as a complementary pole piece for the magnetic pole 150. However, it is not necessarily permanently magnetized. The exposed surfaces of the anode are coated, by plating or otherwise, with copper or other highly conductive material adapted to permit the free circulation of high frequency currents. The whole anode structure is based upon the bottom closure 163 of the container so that a complete magnetic circuit is provided through the container walls.

As appears most clearly in Fig. 7 the anode is provided with a number of radially extending circular channels 165 which communicate with the space above the anode through slots 166. The channels and the slots connect at their inner ends with an opening 167 formed centrally in the anode structure. By virtue of this arrangement the anode is enabled to function as a multi-cavity resonator adapted to be excited by the rotating space charge developed in proximity to its upper surface by the electrons emitted from the cathode 157. The high frequency energy thus developed in the resonant cavities may be utilized externally by the use of a coupling loop (not shown) extending into one of the cavities in the manner indicated in Fig. 1.

The arrangement of Fig. 6 has the particular advantage that no significant magnetic gap exists between the anode 162, viewed as a magnetic pole piece, and the source of the electrons desired to be affected by the magnetic field. Because of this circumstance the effective reluc-

tance of the total magnetic path is reduced. This effect can be still further enhanced by shortening the cathode structure to bring the pole pieces 150 and 162 into closer proximity to one another.

In this patent I do not claim magnetron type discharge devices having transversely extending anode cavity constructions such as those illustrated by Figures 6 and 7 since the invention illustrated thereby is covered broadly by certain claims in my pending application Ser. No. 674,194, filed June 4, 1946, and constituting a continuation in part of the application for this patent.

While the invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without departing from the invention. I therefore aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

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

1. An electronic device comprising a container forming the envelope of said device and having a part of its wall structure constituted of ferromagnetic material, means including a permanently magnetized pole piece within said container for producing a magnetic field in a particular region of the enclosed space, and cooperating electrode elements located in the said magnetic field, said pole piece having a direct magnetic connection with the ferromagnetic part of said wall structure and forming therewith a low reluctance path which is closed except for region of said electrodes.

2. An electronic device comprising an evacuated container having its walls constituted mainly of ferromagnetic material, means including a permanently magnetized pole piece within the container for producing a localized magnetic field, a ferromagnetic member supporting said pole piece and providing a direct magnetic connection between the pole piece and a ferromagnetic portion of the wall of the container, whereby a low reluctance return path is provided for magnetic flux traversing the pole piece, and mutually cooperating discharge electrodes in proximity to said pole piece and within the influence of the said magnetic field.

3. A magnetron device comprising a container forming an envelope of the device and having its lateral walls constituted principally of ferromagnetic material, ferromagnetic members extending transversely of said container and presenting surfaces within the container, a pair of magnetic pole pieces in mutually spaced relation within said container, said pole pieces being respectively supported by said ferromagnetic members, whereby a low reluctance flux path between the remote extremities of said pole pieces is provided through said members and through the lateral walls of the container, and cooperating electrode elements positioned in the space between said pole pieces.

4. Electronic apparatus comprising a container having a substantial part of its wall structure constituted of ferromagnetic material, means including a permanently magnetized pole piece within said container for producing a magnetic field therein, said pole piece having a low reluctance connection with the wall structure of said container whereby said wall structure provides a return path for magnetic flux traversing the pole

piece, and an anode and a cathode in proximity to said pole piece and within the influence of said magnetic field, said cathode comprising an equipotential emitting part, a filamentary heater for said part and a pair of current supply wires for said heater extending axially through one of said pole pieces and sealed through a wall of said container.

5. An electronic discharge device including an elongated cylindrical container forming the envelope of said device and having its lateral walls constituted principally of ferromagnetic material, ferromagnetic members closing the ends of the container, a pair of magnetic pole pieces respectively supported from said members in mutually spaced relation within said container and in magnetic contact with said members, and cooperating electrodes within said container and in the space between said pole pieces.

6. A magnetron device comprising a container providing the envelope of said device and including a hollow cylinder of ferromagnetic material, a self-resonant anode structure supported within said cylinder intermediate its ends, a cathode structure concentric with said anode structure, and magnetic pole pieces within said container adjacent the ends thereof and on opposite sides of said anode structure, each of said pole pieces having a direct ferromagnetic connection with said cylinder whereby the combination of said cylinder and said connections provides a low reluctance return path for magnetic flux traversing the pole pieces.

7. An electronic device comprising an elongated container forming the envelope of said device and having a part of its wall structure constituted of ferromagnetic material, a self-resonant anode structure within said container and intermediate the ends thereof, a cathode in cooperatively spaced relation with respect to said anode structure, magnetic pole pieces within said container on opposite sides of said anode structure and having a low reluctance connection with said container, and spacing means interposed between said anode structure and said pole pieces maintaining them in a predetermined structural relationship.

8. A magnetron comprising an evacuated container constituted principally of ferromagnetic metal, electrodes cooperatively spaced within said container, one of said electrodes being connected directly to the container, another of said electrodes being supported in insulating relationship to said container, and means including a permanently magnetized element within said container for producing a magnetic field in the space between said electrodes, said container having a direct ferromagnetic connection with said element to provide a low reluctance return path for magnetic flux traversing said element.

9. A magnetron device comprising a container providing the envelope of said device and including a hollow cylinder of ferromagnetic material, a self-resonant anode structure supported within said cylinder intermediate its ends, a cathode structure concentric with said anode structure, and pole pieces of permanently magnetized material within said container on opposite sides of said anode structure, said pole pieces each having a direct and continuous ferromagnetic connection with said cylinder whereby the cylinder provides a low reluctance return path for magnetic flux traversing the pole pieces.

ELMER D. MCARTHUR.