

March 9, 1948.

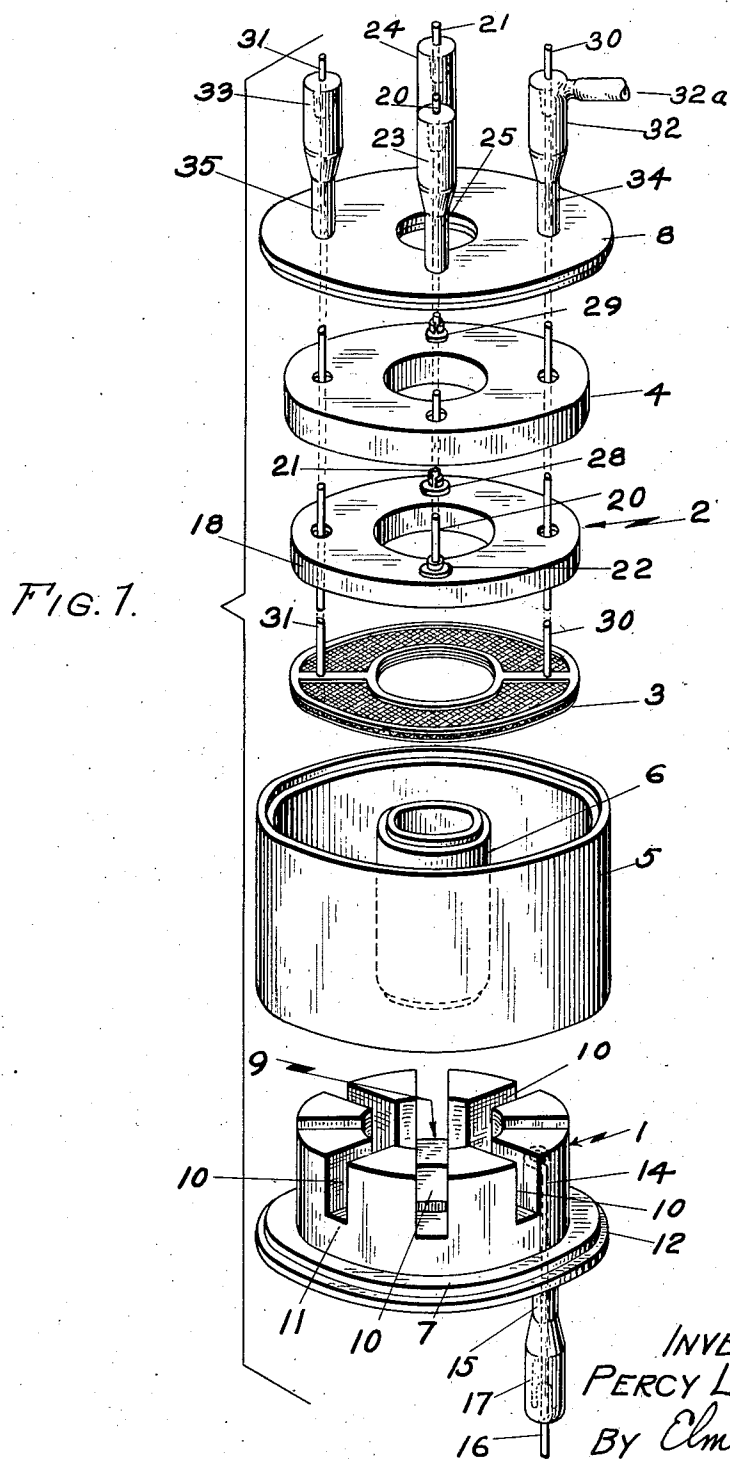
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2,437,279

HIGH POWER MICRO-WAVE DISCHARGE TUBE

Filed Sept. 23, 1942

3 Sheets-Sheet 1



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FIG. 2.

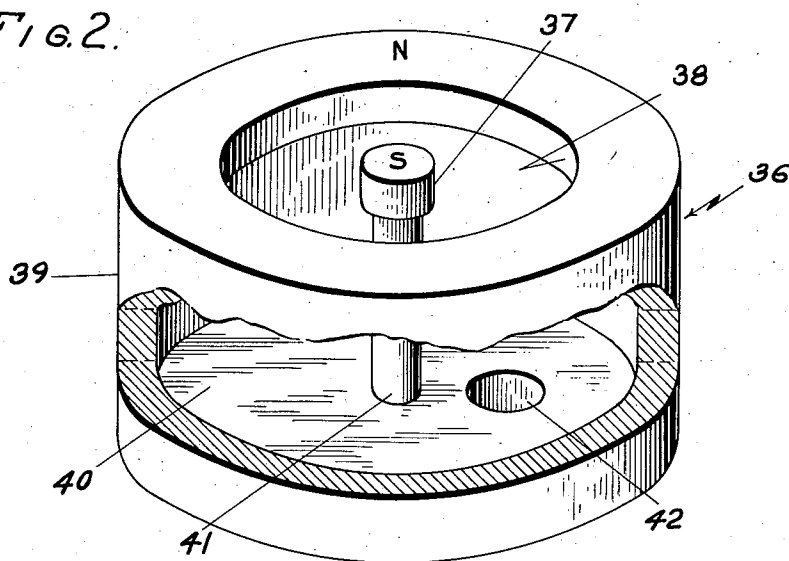
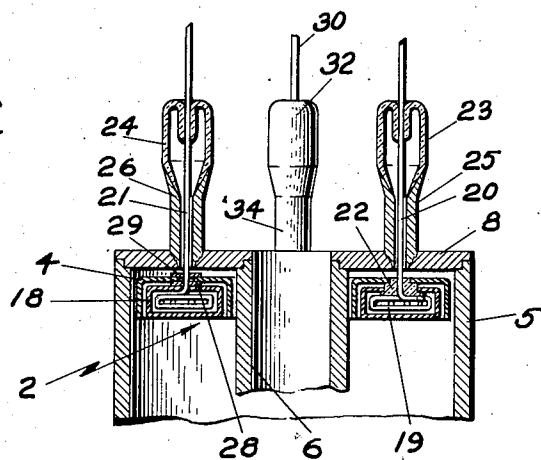


FIG. 6.



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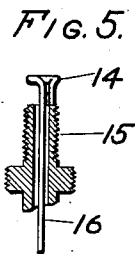
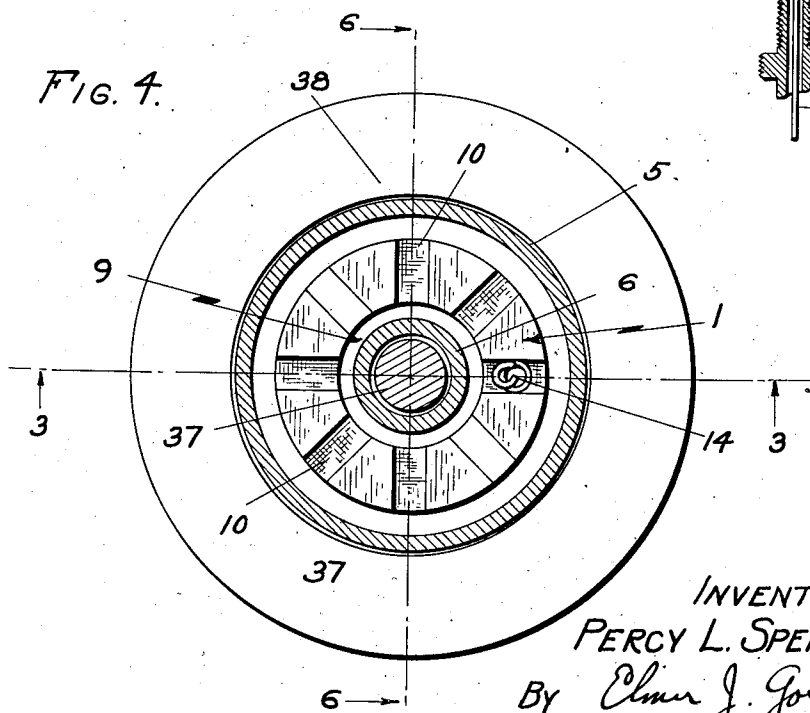
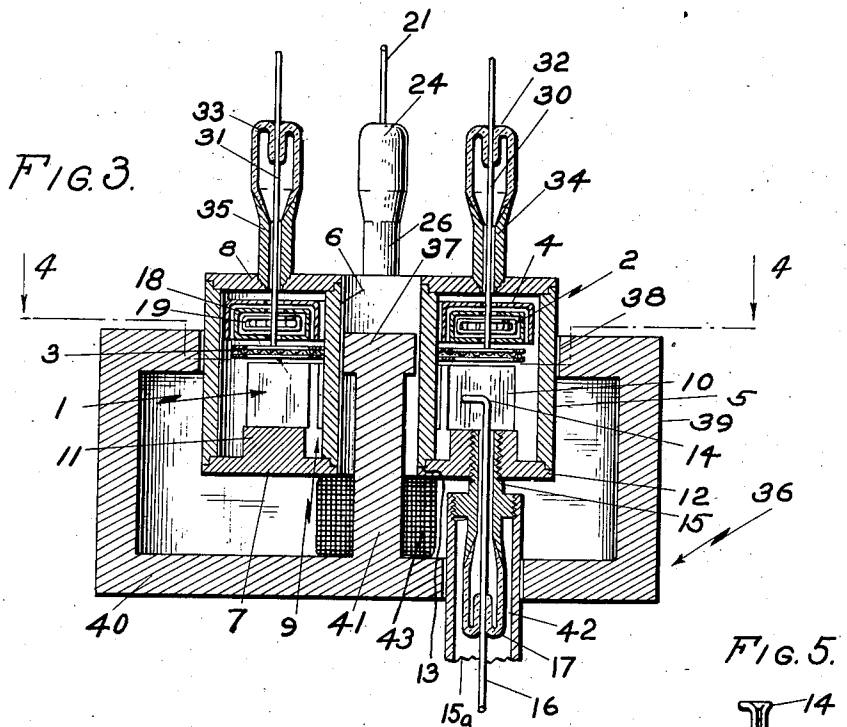
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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HIGH-POWER MICROWAVE DISCHARGE
TUBEPercy L. Spencer, West Newton, Mass., assignor
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Application September 23, 1942, Serial No. 459,347

11 Claims. (Cl. 315—39)

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This invention relates to an electrical space discharge tube of the magnetron type which is adapted to generate micro-waves of high power. This invention relates more particularly to such a tube in which the dimensions of the internal structure determine the frequency of the electrical oscillations produced thereby.

Discharge tubes of the foregoing type have heretofore been constructed with a centrally disposed cathode surrounded by the anode structure. Such an arrangement has imposed a practical limit on the total emitting area of the cathode and thus such tubes have been limited in the amount of current which they could be designed to carry. The foregoing limitation has been particularly severe in the case of microwave oscillators producing wave lengths of the order of a few centimeters or less. In such cases the space available for the cathode decreased in diameter as the wave length decreased so that cathodes of very limited emitting capacity necessarily had to be utilized in such tubes.

An object of this invention is to devise a discharge tube of the foregoing type with a novel configuration in which large cathode emitting surfaces can be utilized and which are capable of carrying large values of load current and in which the size of the cathode may be substantially independent of the wave length of the oscillations generated by such a tube.

In discharge tubes of the magnetron type in which a plurality of separate oscillating paths exist in the anode structure it is important that the natural frequency of all such paths be made equal to each other. Prior anode configurations for tubes of this type have been very difficult to construct so as to obtain this equality with the result that in such tubes a certain amount of interference has existed between the various circuits which interference substantially reduced the efficiency of operation of such tubes.

Another object of this invention is to produce a configuration having a plurality of separate oscillating paths within the electrode structure, which may be accurately and easily machined or otherwise fabricated so that all said oscillating paths are of the same frequency.

Tubes of the foregoing type are often employed in systems where the device is called upon to produce pulses of oscillations of relatively high intensity. Such pulsing operations have necessitated apparatus for the control of substantially all of the power fed to such device.

Another object of this invention is to produce an arrangement in which a grid electrode may

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be utilized to control the operation of the device, thus requiring only the control of the relatively small grid power in order to produce pulsing operations.

5 A further object is to devise a novel configuration of magnetron which possesses the advantages of ease of manufacture and assembly and which enables auxiliary electrodes to be utilized therein.

10 The foregoing and other objects of this invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawings wherein:

15 Fig. 1 is an exploded perspective view of a discharge tube embodying my invention;

Fig. 2 is a perspective view partly in section of a magnet structure with which the tube of Fig. 1 may be utilized;

20 Fig. 3 is a cross-sectional view of the tube shown in Fig. 1 after said tube has been assembled, the section of Fig. 3 being taken along line 3—3 of Fig. 4;

Fig. 4 is a cross-sectional view of the tube taken 25 along the line 4—4 of Fig. 3;

Fig. 5 is a cross-sectional detail of the mounting of the oscillation pick-up loop; and

Fig. 6 is a fragmentary cross-sectional view of the tube taken along line 6—6 of Fig. 4.

30 The tube as illustrated in the drawings consists of an anode structure 1 which is formed of a suitable conducting material, such as high conductivity copper, and a cathode structure 2. If desired a grid electrode 3 may be interposed between the anode 1 and the cathode 2 in order to provide for control of the discharge between said electrodes. The cathode structure 2 is in the form of a hollow flat annular shaped ring of which the lower surface is adapted to be the active 35 electron emitting surface. Preferably, therefore, a heat shield 4 is adapted to be placed over the upper surfaces of the cathode 2 in order to prevent excess loss of heat from the non-emitting surfaces of the cathode.

45 The foregoing elements are adapted to be mounted in a casing consisting of an outer sleeve 5, an inner sleeve 6, and end caps 7 and 8 which engage the outer ends of the sleeves 5 and 6 and close off the annular space formed between said sleeves. Each of the elements 5, 6, 7 and 8 may 50 likewise be formed of suitable conducting material, such as, copper. If desired, the end cap 7 may be formed integrally with the anode 1, or said elements may be formed separately and then fastened together as by being brazed to each other

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with silver solder. The end cap 8 is adapted to carry the cathode 2, the grid 3, and the cathode heat shield 4, all of which may be assembled on said end cap 8 prior to their assembly with the rest of the tube structure.

The anode 1 is formed from an annular block of metal containing a central bore 9. A plurality of radial slots 10 are cut from one end of the annular block and are of a predetermined depth less than the total length of said block thus leaving a solid end ring portion 11. As stated above this anode structure may be integral with or otherwise fastened to the lower end cap 7. The cap 7 extends beyond the outside boundary of the anode 1 and is provided with a stepped outer edge 12 adapted to fit into the lower end of outer sleeve 5 which is correspondingly stepped. The cap 7 likewise extends inwardly beyond the inner walls of the bore 9 and is provided with an inner stepped edge 13, also adapted to fit onto the lower end of the inner sleeve 6 which is correspondingly stepped. In order to lead off the oscillations which are generated in the tube, there is provided a coupling loop 14 which is placed in one of the slots 10 with its plane transverse to said slot. The coupling loop 14 is carried by a pipe 15 which is hermetically sealed in an opening extending through the cap 7 and the end ring portion 11 of the anode 1. One end of the coupling loop 14 is directly connected to the inner end of the pipe 15 as shown most clearly in Fig. 5. The other end of the coupling loop 14 is connected to a lead wire 16 which passes through a glass seal 17 sealed to the outer end of the pipe 15. An outer pipe 15a may be screw threaded onto the outer surface of the pipe 15 to form with the conductor 16 a concentric line through which the oscillations may be conducted to a suitable utilization device.

The cathode 2 is formed of a hollow toroidal member 18 of a suitable conducting material, such as nickel. This member is coated on its lower face with suitable electron emissive materials, such as the alkaline earth oxides. It will be seen that in this way a relatively extensive electron emitting area is provided. The emitting area of the cathode is heated by a coiled heater 19 of refractory material, such as tungsten or the like. The coil of the heater 19 may be likewise bent into the proper toroidal shape to fit within the hollow interior of the member 18. A suitable form of the coil heater 19 may be a closed spiral, to which is connected, at two diametrically opposed points, a pair of lead-in wires 20, 21 for supplying heating current to the coil 19. Preferably the coil 19 is coated with an insulation coating so as to prevent short-circuiting thereof by the member 18. The lead-in conductors 20 and 21 pass through openings provided in the upper surface of the member 18. The conductor 20 is insulated from the member 18 by a stepped insulator 22 which is mounted within the opening through which the lead wire 20 passes. The conductor 21, however, is electrically connected to the member 18 and thus may serve as a lead for the cathode discharge current as well as one of the heater leads. The cathode structure is supported by the conductors 20 and 21 from a pair of glass seals 23 and 24 sealed to the outer ends of a pair of conducting pipes 25 and 26 hermetically sealed in openings extending through the upper end cap 8.

As previously stated a light metal heat shield 4 may be utilized to prevent excessive heat losses from the back portion of the cathode. Conduc-

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tors 20 and 21 thus likewise pass through openings in the heat shield 4. In order to prevent short-circuiting of the heater coil 19, the stepped insulator 22 also extends into the opening in the shield 4 through which the conductor 20 extends. The heat shield 4 is preferably spaced a short distance from the back surface of the member 18. The outer step in the insulator 22 provides the proper spacing for one side of the heat shield 4. The other side of the shield 4 may be spaced by a conducting washer 28 of the proper thickness which may be welded to the members 18 and 21. The heat shield may be retained firmly in place by an outer conducting washer 29 likewise welded to the conductor 21 and to the member 4. By the foregoing construction the shield 4 is electrically connected to the cathode and maintained at the cathode potential.

Although most tubes of the foregoing type operate without the interposition of a grid electrode between the cathode and the anode, if desired such a grid electrode 3 may be utilized in the present construction. The grid electrode 3 may be formed of a mesh material preferably with an end binding of metal so as to strengthen it. The grid electrode is likewise formed as a flat washer and may be supported by a pair of lead-in conductors 30 and 31. These lead-in conductors preferably lie in a plane at right angles to the plane containing the lead-in wires 20 and 21. The lead-in conductors 30 and 31 are insulated from the cathode 2 by passing through openings in the upper and lower surfaces of the member 18 and through corresponding openings in the heat shield 4. If necessary, insulators might be inserted in such openings so as to insure against electrical contact between the conductors 30 and 31 and any of the cathode structure. The conductors 30 and 31 likewise pass between turns of the coiled heater 19. If necessary the coils may be spread so as to provide for such passage. In any event since the coil 19 is coated with insulation the danger of contact with the conductors 30 and 31 is substantially eliminated. The conductors 30 and 31 are supported by glass seals 32 and 33 sealed to the outer ends of pipes 34 and 35 likewise hermetically sealed in openings extending through the top end cap 8.

In order to assemble the tube construction, the anode 1 and coupling loop 14 are mounted on the lower end cap 7. Likewise the members 2, 3 and 4 are mounted on the upper end cap 8. As described in connection with the lower end cap 7, the upper end cap 8 is likewise provided with outer and inner stepped edges which fit on the correspondingly stepped edges of the sleeves 5 and 6. The end caps 7 and 8 carrying their associated members are then inserted onto the lower and upper ends respectively of the sleeves 5 and 6. All joints are then hermetically sealed as by brazing with a silver solder. I have found that this is a very effective way of producing a completely hermetically sealed structure.

The tube as assembled above may then be exhausted in the usual manner through an exhaust tube, such as 32a, provided on one of the glass seals 32. After the tube is degasified and exhausted, the exhaust tube 32a is sealed off in accordance with the well known practice.

After the tube has been completed as described above it may be inserted between the poles of a suitable magnet structure. Such a structure 36 is shown, for example, in Figs. 2 and 3. The structure 36 is provided with a central pole piece 37 and a surrounding annular pole piece 38, thus

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providing an annular gap across which radial magnetic lines of force are adapted to pass. The annular pole piece 38 is mounted at the outer end of a cylindrical side casing 39 which is provided with a flat bottom wall 40. In the center of the bottom wall 40 is mounted a central leg 41 which carries the central pole piece 37 at its upper end. The entire structure 36 is preferably made of a highly magnetic material. The tube may be inserted into the annular gap between the pole pieces 37 and 38 until the discharge space between the cathode and the anode is located in the radial magnetic field existing between the pole pieces. An opening 42 may be provided in the lower wall 41 to let the pipe 15a pass through. The magnet 36 may be formed as a permanent magnet or if desired an energizing coil such as indicated at 43 in Fig. 3 may be utilized to supply the magnetomotive force necessary to create the magnetic flux.

For those operations in which it is desired to have the grid electrode control pulsing operations of the tube, the position of the tube is adjusted so that the top edges of the magnetic poles 37 and 38 lie just below the lower surface of the grid electrode 3. In this way the magnetic field is substantially limited to the region adjacent the anode electron receiving surfaces, and the grid electrode 3 is located in a substantially magnetic field free space. Of course it is to be understood that the spacing between the electrodes and the various other spacial relationships are illustrated merely diagrammatically in the drawings. Thus, if necessary the spacings could be greatly increased if required to provide the proper magnetic field substantially limited to the region adjacent the electron receiving surfaces of the anode, and to provide a substantial magnetic field free space in which the grid is to be placed. With such an arrangement the electrons emitted from the cathode are under complete control of the grid before being subjected to the magnetic field. Thus, for example, the grid electrode 3 could modulate electron flow and in this way modulate the oscillations generated. Where pulsing is desired, the proper potential could be impressed on the grid 3 at the proper time intervals to completely cut off the electron flow or to permit it to pass, thus producing pulses of oscillations separated by the proper time intervals.

When the various elements of the tube are energized with the proper potentials, electrons are emitted from the lower face of the member 18. The electrons so emitted are attracted toward the anode by the positive potential impressed hereon and in so doing come under the influence of the magnetic field existing in the inter-electrode space. Thus, for example, a particular electron may be attracted toward one of the anode segments formed between two slots 10. The magnetic field, however, being transverse to the electrostatic field deflects the electron in a curvilinear path at right angles to the fields. Thus, said electron, instead of reaching the anode segment which accelerated it, falls on an adjacent segment of the anode. This action feeds energy to said adjacent segment and causes oscillations to be generated within the anode structure. This action, of course, is the well known operation which exists in magnetrons of the multiple anode type. Each pair of adjacent anode segments together with the portion of the ring 11 joining them form a circuit containing inductance and capacitance. This constitutes a tuned oscillating circuit whose frequency is determined

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by said inductance and capacitance. All of these circuits which exist in the anode structure are electrically connected. This is due to the fact that each segment forms an integral part of two adjacent oscillating circuits. Thus, if all of these circuits are tuned to the same frequency, they will reinforce each other and the entire tube will generate oscillations of relatively high power which may be led by the lead 16 and the pipe 15a to any suitable utilization device.

Due to the foregoing arrangement, tubes of this kind may be made capable of carrying high values of cathode discharge current independent of the frequency which such a tube is adapted to generate. This is due to the fact that large emitting surfaces for the cathode may be utilized in such an arrangement. Furthermore, it is relatively easy to obtain an exact equality of tuning between the various oscillating circuits. This is due in large measure to the fact that the slots are of simple configuration, easily accessible for machining or other fabrication. It is the dimensions of each of these slots which determine the frequency of each of the oscillating circuits.

Of course it is to be understood that this invention is not limited to the details of construction as described above inasmuch as many equivalents will suggest themselves to those skilled in the art.

What is claimed is:

1. An electrical space discharge device comprising a cathode, an anode, said anode having a plurality of sections having electron receiving surfaces disposed substantially in a plane, said surfaces being spaced from each other, said cathode having an electron emitting surface disposed substantially in a plane substantially parallel to the plane of said electron receiving surfaces, and means adjacent the discharge path between said planes for producing a magnetic field transverse to said discharge path.

2. An electrical space discharge device comprising a cathode, an anode, said anode having a relatively extended side disposed substantially in a plane, said anode having a plurality of slots extending from said side at an angle to said plane, said cathode having an electron emitting surface disposed substantially in a plane substantially parallel to the plane of said anode side, and means adjacent the discharge path between said planes for producing a magnetic field transverse to said discharge path.

3. An electrical space discharge device comprising a cathode and an anode, said anode being an annular shaped conductor having one end disposed substantially in a plane, said anode having a plurality of slots extending from said end at an angle to said plane, the surfaces of said end of said anode between said slots forming electron-receiving surfaces, said cathode having an electron emitting surface disposed substantially in a plane substantially parallel to the plane of said anode end.

4. An electrical space discharge device comprising a cathode and an anode, said anode being an annular shaped conductor having one end disposed substantially in a plane, said anode having a plurality of radially disposed slots extending from said end at an angle to said plane, the surfaces of said anode between said slots forming electron-receiving surfaces, said cathode having an electron emitting surface disposed substantially in a plane substantially parallel to the plane of said anode end.

5. An electrical space discharge device com-

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prising a cathode, an anode, said anode being an annular shaped conductor having one end disposed substantially in a plane, said anode having a plurality of slots extending from said end at an angle to said plane, the surfaces of said anode between said slots forming electron-receiving surfaces, said cathode having an electron emitting surface disposed substantially in a plane substantially parallel to the plane of said anode end, and means adjacent the discharge path between said planes for producing a magnetic field transverse to said discharge path.

6. An electrical space discharge device comprising a cathode, an anode, said anode being an annular shaped conductor having one end disposed substantially in a plane, said anode having a plurality of slots extending from said end at an angle to said plane, the surfaces of said anode between said slots forming electron-receiving surfaces, said cathode having an annular shaped electron emitting surface disposed in a plane substantially parallel to the plane of said anode end, and means adjacent the discharge path between said planes for producing an annular magnetic field extending radially and transverse to said discharge path.

7. An electrical space discharge device comprising a cathode, an anode, said anode having a plurality of sections having electron receiving surfaces disposed substantially in a plane, said surfaces being spaced from each other, said cathode having an electron emitting surface disposed substantially in a plane substantially parallel to the plane of said electron receiving surfaces, a control grid disposed in the space between said two planes, and means adjacent the discharge path between said planes for producing a magnetic field transverse to said discharge path.

8. An electrical space discharge device comprising a cathode, an anode, said anode having a plurality of sections having electron receiving surfaces, said surfaces being spaced from said other, said cathode having an electron emitting surface spaced from said electron receiving surfaces, means adjacent the discharge path between said cathode and anode for producing a magnetic field transverse to said discharge path, said magnetic field being limited substantially to a space adjacent said anode, and a control grid disposed in the space between said cathode and anode which is substantially magnetic field free.

9. An electrical space discharge device comprising a cathode, an anode, said anode having a plurality of sections having electron receiving

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surfaces disposed substantially in a plane, said surfaces being spaced from each other, said cathode having an electron emitting surface disposed substantially in a plane substantially parallel to the plane of said electron receiving surfaces, means adjacent the discharge path between said planes for producing a magnetic field transverse to said discharge path, said magnetic field being limited substantially to a space adjacent said anode, and a control grid disposed in the space between said two planes which is substantially magnetic field free.

10. An electrical space discharge device comprising a cathode, an anode incorporating a plurality of cavity resonators, said anode including a plurality of sections providing a plurality of spaced electron receiving surfaces all of which are disposed in a single plane, and said cathode having an electron emitting surface disposed in a plane parallel to the plane of said electron receiving surfaces, and a control grid disposed between said two planes.

11. An electrical space discharge device comprising an anode incorporating a plurality of cavity resonators, said anode including a plurality of sections providing a discontinuous annular electron receiving surface, a cathode, spaced from said anode, and having an electron emitting surface parallel to the electron receiving surface of said anode, an auxiliary electrode disposed adjacent said anode and said cathode, and means adjacent the discharge path between said anode and said cathode for producing a magnetic field transverse to said discharge path.

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Certificate of Correction

Patent No. 2,437,279.

March 9, 1948

PERCY L. SPENCER

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 5, line 56, for the word "hereon" read *thereon*; column 7, line 42, claim 8, for "said" second occurrence read *each*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 4th day of May, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.