Aug. 9, 1949. P. L. SPENCER 2,478,644

ELECTRICAL DISCHARGE DEVICE OF THE MAGNETRON TYPE

Filed Oct. 23, 1943 3 Sheets-Sheet 1

FIG. 1.

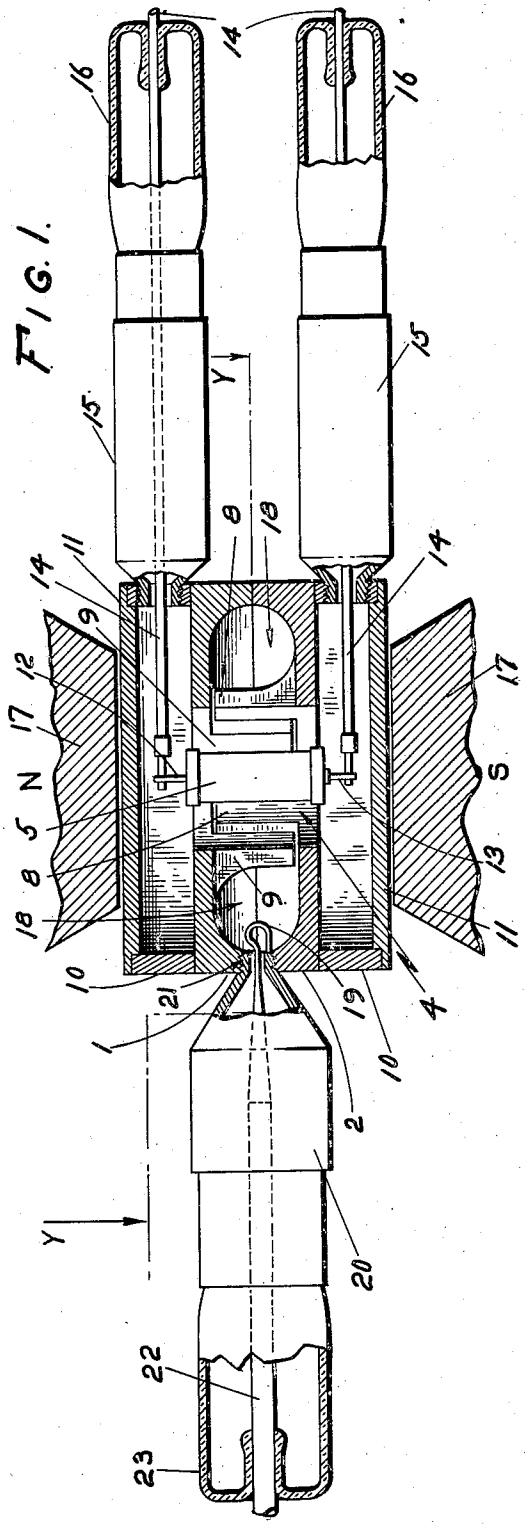
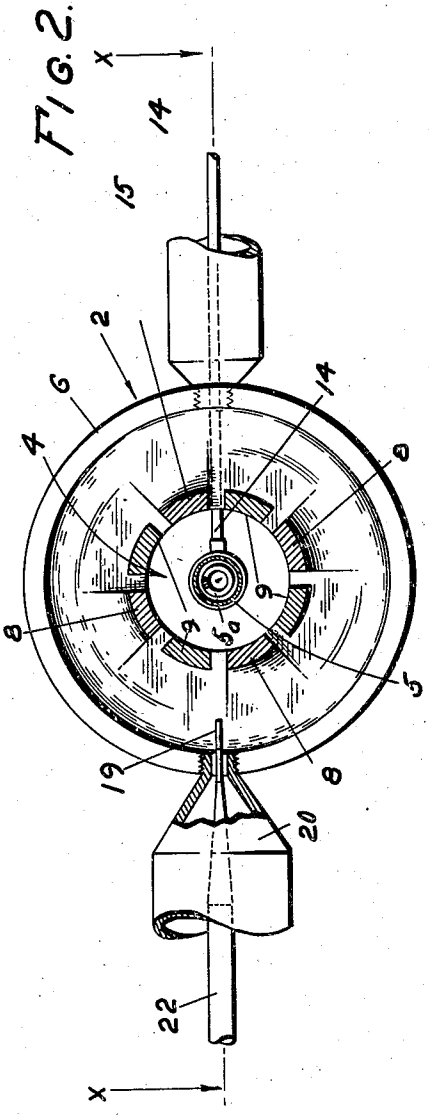


FIG. 2.



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ELECTRICAL DISCHARGE DEVICE OF THE MAGNETRON TYPE

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FIG. 3.

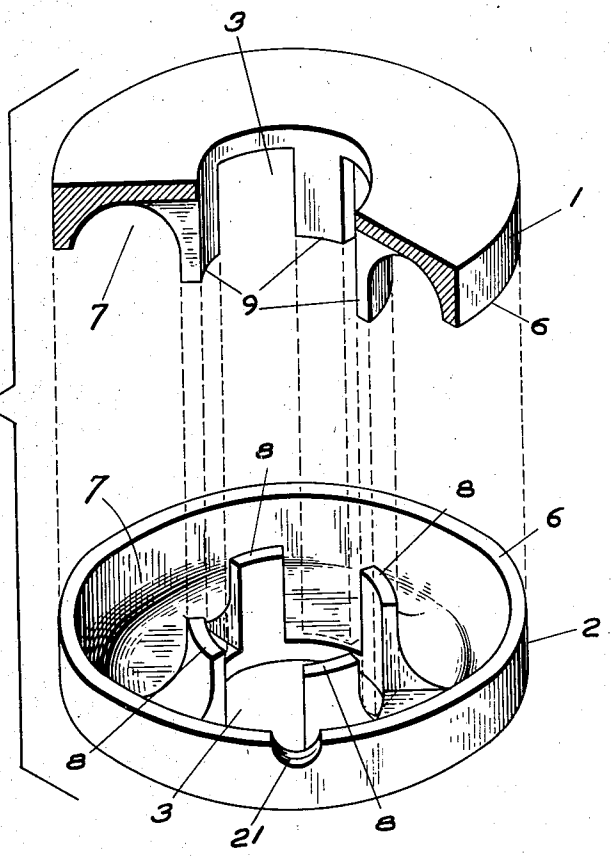
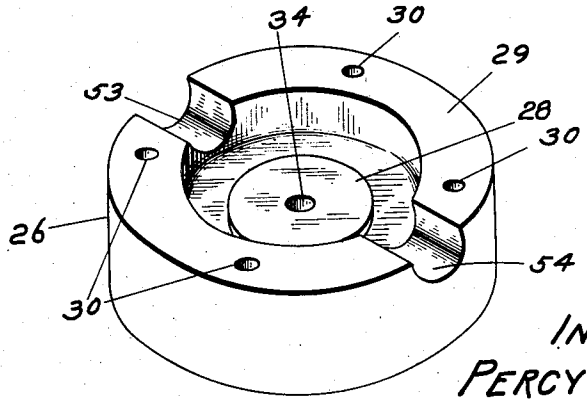


FIG. 5.



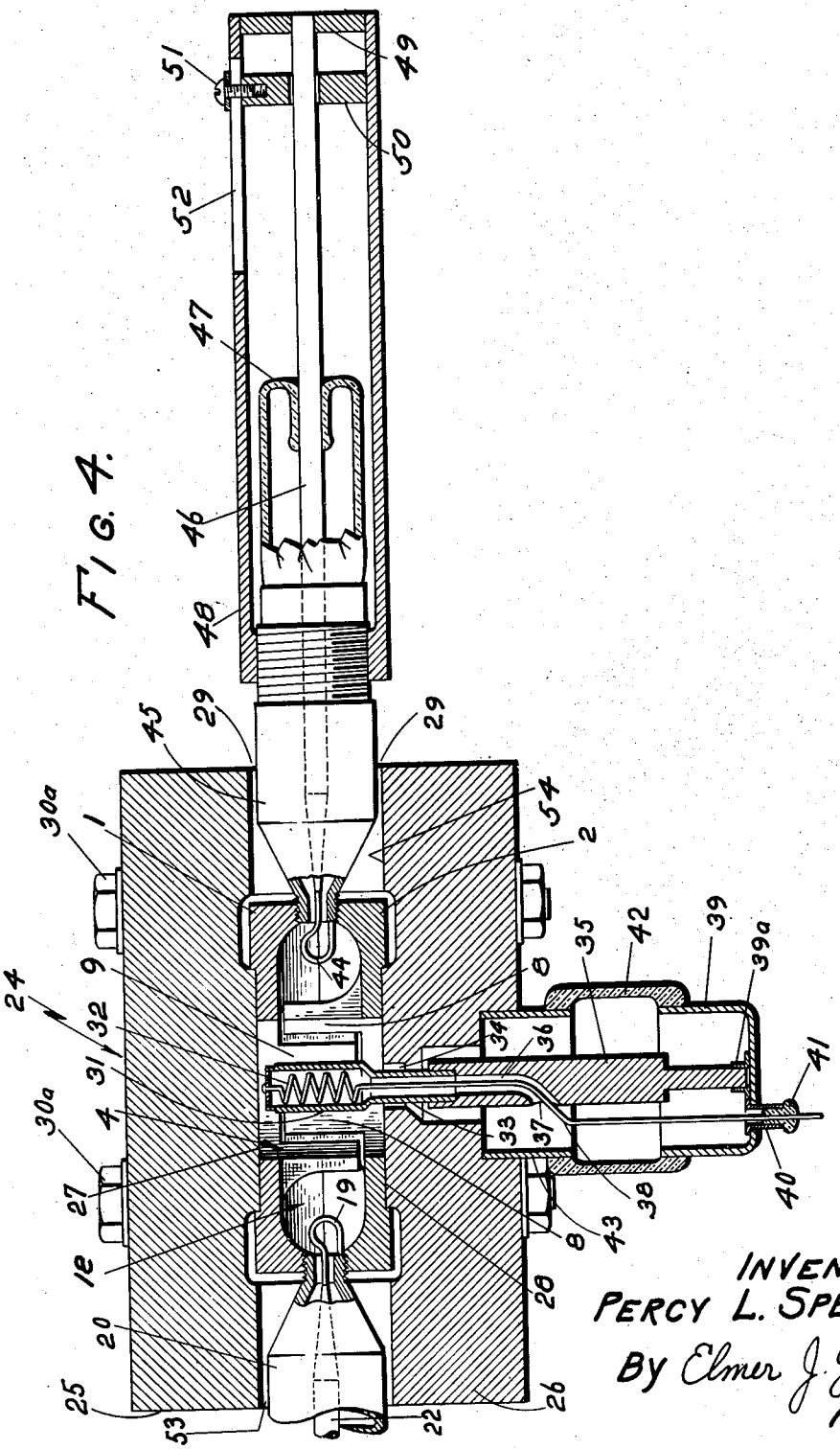
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FIG. 4.



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Patented Aug. 9, 1949 2,478,644

UNITED STATES PATENT OFFICE

2,478,644

ELECTRICAL DISCHARGE DEVICE OF THE MAGNETRON TYPE

Percy L. Spencer, West Newton, Mass., assignor to Raytheon Manufacturing Company, Newton, Mass., a corporation of Delaware

Application October 23, 1943, Serial No. 507,450

8 Claims. (Cl. 315—40)

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This invention relates to a magnetron, and more particularly to one of the multiple anode type in which the internal structure provides a plurality of oscillating circuits, all of which are intended to oscillate at the same frequency and thus to contribute to the effective output of the magnetron. Heretofore difficulties have been encountered in constructing each of the oscillating circuits to have exactly the same natural frequency and providing a sufficiently close coupling between all of these circuits so that small differences in the constants of the circuits would be overcome and all of the circuits oscillate at the same output frequency with maximum effectiveness. In such magnetrons also a tendency has existed for the device to oscillate in various spurious modes in addition to the principal mode which determines the desired output frequency.

An object of this invention is to devise a magnetron of the foregoing type in which the probability of exact equivalence in the natural frequency of each of the possible oscillating circuits therein is greatly increased.

Another object is to devise an arrangement in which all of the oscillating circuits are closely coupled through the shortest possible path.

Another object is to devise such an arrangement in which the possibility of the device to oscillate in undesired spurious modes is reduced substantially to a minimum.

A further object is to devise an arrangement in which the coupling between the oscillating portion of the device and the output is substantially increased.

A still further object is to devise an arrangement whereby all of the possible oscillating circuits may be tuned in a simple and direct manner.

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

Fig. 1 is a longitudinal cross-section of a magnetron embodying my invention taken along line X—X of Fig. 2;

Fig. 2 is a transverse cross-section taken along Y—Y of Fig. 1;

Fig. 3 is a perspective view of the two halves of the anode structure separated from each other, with the upper half partly broken away;

Fig. 4 is a longitudinal cross-section of another embodiment of my invention; and

Fig. 5 is a perspective view of the lower half of the magnet structure of the arrangement shown in Fig. 4.

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The magnetron illustrated in Figs. 1, 2 and 3 comprises an anode structure consisting of two halves 1 and 2, each constructed of a suitable highly-conducting material, such as copper. Each of the anode halves 1 and 2 is in ring form with a central opening 3. When the two anode halves are assembled together, the openings 3 together form a central bore 4 extending through the anode structure and forming a chamber within which a cathode 5, preferably of the indirectly-heated thermionic type, is supported. Each anode half 1 and 2 is formed with an outer upstanding ring section 6 surrounding a substantial semi-circular cavity section 7. A plurality of upstanding fingers 8 project from the inner side of the cavity section 7 in the lower anode half 2. The inner faces of the upstanding fingers 8 constitute anode portions adapted to receive electrons emitted from the cathode 5. The upper anode half 1 is provided with a plurality of similar fingers 9 projecting from the inner side of the cavity section 7. The fingers 8 and 9 are equally spaced around their respective openings 3. The edges of the rim sections 6 are adapted to be brought into contact with each other in such a way that each of the fingers 9 is spaced between two fingers 8, as indicated by the dotted lines in Fig. 3. When the two anode halves 1 and 2 are assembled in this way, the anode structure is hermetically joined along the contacting edges of the ring 6, preferably by silver-soldering so as to form a unitary anode assembly.

In order to complete the tube assembly, the anode structure is provided with a pair of end rings 10, each provided with an end cap 11. The rings 10 and caps 11 are likewise adapted to be hermetically sealed in place, preferably by silver-soldering. The cathode 5 is provided with a pair of leads 12 and 13 connected to the opposite ends of an internal heater 5a. One of these leads, for example 13, is likewise adapted to be electrically connected to the outer conducting sleeve of the cathode 5 which may be coated with the usual emitting oxides. The cathode 5 is supported by a pair of cathode conductors 14 which are connected respectively to the cathode leads 12 and 13. The conductors 14 extend through pipes 15 hermetically sealed through openings in the rings 10 carrying glass seals 16 at their outer ends. The conductors 14 are sealed through said glass seals.

When the magnetron structure described above is placed between suitable magnetic poles

17 and proper voltages are applied thereto, oscillations are generated within the anode structure. It will be noted that when the upper and lower anode halves 1 and 2 are joined together, they form an annular chamber 18 through which the oscillations generated are readily propagated, and which in effect constitutes an annular cavity resonator. The oscillatory energy which is propagated through the annular chamber 18 may be led off to a suitable utilization device by means of a coupling loop 19 which extends into the annular chamber 18, and couples to the magnetic component of the oscillatory fields set up within said annular chamber. One end of the coupling loop 19 is connected to the inner end of a conducting pipe 20 hermetically sealed through an opening 21 in the side of the anode structure. The other end of the coupling loop 19 is connected to a conductor 22 which passes through the pipe 20 and emerges therefrom through a glass seal 23 carried at the outer end of said pipe. The conductor 22 together with an external pipe, not shown, which may be connected electrically to the pipe 20, form a concentric transmission line through which the oscillations may be conducted to any suitable load device.

When the tube described above is in its oscillating condition, the fingers 8 and 9 are of opposite phase so that oscillating currents tend to flow between alternating fingers 8 and 9. It will be noted that a conducting circuit extends between each finger 8 and its adjacent finger 9, and that this circuit in each case extends in a circular path through the wall of the annular chamber 18. Such a circular path contains a definite amount of inductance. Likewise a capacity exists between the adjacent fingers 8 and 9. Thus each of the above circuits constitutes tuned oscillatory circuits whose natural frequency is determined by the inductance and capacity thereof. As already indicated, the fingers 8 and 9 are of opposite voltage phase so that when a finger 8 is positive, the adjacent finger 9 is negative, and on the next half cycle the voltage conditions are reversed. Therefore oscillatory currents will flow between the fingers 8 and 9 through the walls of the annular chamber 18 in a direction to create an annular magnetic field in said annular chamber. All of said currents are in phase with each other, and thus all of said magnetic fields are likewise in phase, producing a strong resultant annular magnetic field. This resultant annular magnetic field couples all of the oscillating circuits, and thus tends to make the inductance of all of said oscillating circuits equal. It is comparatively simple to construct the arrangement so that the capacity between each pair of anode fingers is likewise equal. Therefore, in the above arrangement, the device, due to its structure, tends to make the natural frequency of each of the oscillating circuits exactly equal. In addition, the magnetic field closely couples all of the oscillating circuits by the shortest possible path, producing a very close coupling which forces all of said oscillating circuits to oscillate exactly at the same frequency, even though slight differences in the natural frequencies of said circuits might otherwise tend to exist.

As pointed out in my copending application, Serial No. 421,145, filed December 1, 1941, and now U. S. Patent No. 2,417,789, granted March 18, 1947, tendencies have existed for magnetrons of the multiple anode type to oscillate in various spurious modes, which tendency can be substantially eliminated by directly interconnecting alternate anode electron-receiving sections by a low impedance connector, which arrangement is known as "strapping." It will be seen that the flat end wall of anode half 1 directly electrically ties together the anode fingers 9, while the flat end wall of the anode half 2 directly electrically ties together the anode fingers 8. It will further be noted that these flat anode end walls constitute connectors of very low impedance. In this way the structure accomplishes a "strapping" action in a very effective manner.

The coupling loop 19 is directly coupled with the annular oscillatory magnetic field in the annular chamber 18. In this way the energy of each of the oscillating circuits is fed in the most direct path possible into said coupling loop, which thereupon feeds this energy through the conductor 22 as a part of a concentric transmission line to a suitable load device.

Instead of the arrangement as shown in Figs. 1 and 2, my invention lends itself to the construction of a very compact type of device, as is illustrated in Figs. 4 and 5. In these figures, the same reference numerals which are used in Figs. 1, 2 and 3 are applied where the elements are substantially identical. In Figs. 4 and 5 the central bore 4 of the anode structure is closed directly by the pole pieces of a magnet structure 24. This magnet structure is preferably made of a material of high magnetic retentivity formed as a permanent magnet. The magnet structure may likewise be formed of an upper half 25 and a lower half 26. The upper half 25 is provided with a pole piece 27 fitting into and hermetically soldered in a corresponding recess in the top of the upper anode half 1. The lower magnet half 25 is likewise provided with a pole piece 28 fitting into and hermetically soldered in a corresponding recess in the bottom of the lower anode half 2. Each of the magnet halves 25 and 26 is formed with an upstanding rim portion 29, the edges of which are adapted to be brought into contact with each other when the magnet poles 27 and 28 are soldered in place on the anode structure. In order to assist in holding the two magnet halves 25 and 26 together, each magnet half may be provided with a series of bolt-holes 30, as shown for example in Fig. 5, through which suitable bolts 30*a*, may extend and firmly clamp the magnet structure in place on the anode structure. The arrangement, as shown in Figs. 4 and 5, lends itself to the utilization of a novel cathode construction, as described and claimed in the copending application of William C. Brown, Serial No. 503,622, filed September 24, 1943, now Patent Number 2,416,899. The cathode proper comprises a tubular conducting sleeve 31 coated with the usual electron-emitting oxides. Within the sleeve 31 is supported a suitable filamentary heater 32, one end of which is electrically connected to the top closed end of the sleeve 31. The sleeve 31 is formed with a lower reduced tubular end 33 which passes through an opening 34 formed in the pole piece 28. The lower end of the reduced tubular section 33 fits into a recess in the upper end of a conducting rod 35 provided with a bore 36 leading to the interior of the hollow cathode structure. The bore 36 is provided with a side opening 37 through which an insulated wire 38 connected to the lower end of the heater 32 projects. The conductors 35 and 38 thus form the lead-in connections for supplying heating current to the filament 32, and also for supplying a biasing potential to the

cathode. The conductor rod 35 is rigidly secured to an end cup 39 of conductive material by suitable means, such as an eyelet 39a. The conductor 38 passes through an eyelet 40 brazed in an opening in the cup 39, and is hermetically sealed therethrough by a glass seal 41. The cup 39 is insulated from the lower magnet half 26 by means of a glass tube 42 which has one end hermetically sealed to the upper end of the cup 39. The opposite end of the glass tube 42 is similarly sealed to a tubular metal shell 43. The upper end of said metal shell is inserted into an enlarged end of the opening 8 in the lower magnet half 26, and hermetically joined therewith as by brazing. The lower magnet half 26 together with the cathode structure and its lead-in connections and seals thus form an integral assembly which may be readily constructed and thereafter easily assembled with the anode structure of the magnetron.

The arrangement thus far described in connection with Figs. 4 and 5, when energized with proper potentials, produces oscillations as described in connection with the previous modification, which oscillations are fed out by means of the coupling loop 19 and conductor 22 to a suitable load device.

Since the annular cavity resonator chamber 18 is closely coupled with and therefore common to all of the oscillating circuits, a variation of the capacity or inductance values of said annular chamber 18 will produce a corresponding change in the natural frequency of the oscillating system, and thus produce a tuning of the entire device. While variations in these impedance constants of the annular chamber 18 may be carried out in any suitable manner, such as those which have been developed in connection with the tuning of cavity resonators, a preferred arrangement for accomplishing such tuning is also illustrated in Fig. 4. For this purpose a coupling loop 44 similar to the coupling loop 19 is inserted into the annular chamber 18. One end of the coupling loop 44 is connected to the inner end of a hollow pipe 45 hermetically sealed through an opening in the side wall of the anode structure. The other end of the coupling loop 44 is connected to a conductor 46 which extends through a glass seal 47 carried at the outer end of the pipe 45. Surrounding the conductor 46, particularly as it emerges from the glass seal 47, is a hollow tubular conducting member 48 which may be screw-threaded onto a portion of the pipe 45 and thus supported in place substantially concentric with the conductor 46. The outer end of the tubular member 48 may be closed by an end plug 49 which may serve as a centering and supporting member for the outer end of the conductor 46. The hollow member 48 together with the conductor 46 may be caused to function as a tuning chamber by providing a tuning plug 50 filling the space between the conductor 46 and the hollow member 48, and being adjustable along said hollow member 48. This adjustment may be provided by means of a set screw 51 received into one side of the plug 50 and projecting through a slot 52 in the side of the hollow member 48. The plug 50 may be adjusted along the hollow member 48 to impart to said member the proper characteristics, and may then be secured in place by tightening the set screw 51. By proper dimensioning of the hollow member 48, the hollow chamber formed therein, as defined by the position of the plug 50, may be caused to reflect either inductance or capacity into the tubular chamber 18, and thus change the natural frequency at which said annular chamber and thus each of the oscillating circuits therein tend to oscillate.

It will be noted that the upper and lower magnet halves 25 and 26 are formed with suitable openings 53 and 54 through which the pipes 20 and 45 project.

Of course it is to be understood that this invention is not limited to the particular details as described above as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. An electron discharge device comprising: a cathode; and an anode structure spaced from and concentrically disposed about said cathode; said anode structure including a hollow, annular body having a central opening defined by a plurality of overlapping electron-receiving anode portions projecting alternately from upper and lower halves of said body and lying in the surface of a cylinder; a pair of rings extending from opposite sides of said body; cap members closing the outer ends of said rings; and a pair of cathode leads electrically connected to said cathode and extending exteriorly of said device through said rings; said cathode leads lying in planes intermediate said anode structure and said caps.

2. An electron discharge device comprising: a cathode; an anode structure spaced from and concentrically disposed about said cathode; said anode structure including an annular cavity resonator having a central opening defined by a plurality of overlapping electron-receiving anode portions projecting alternately from upper and lower halves of said cavity resonator and lying in the surface of a cylinder; a pair of rings extending from opposite sides of said cavity resonator; cap members closing the outer ends of said rings; a pair of cathode leads electrically connected to said cathode and extending exteriorly of said device through said rings; said cathode leads lying in planes intermediate said anode structure and said caps; and means, extending into said cavity resonator, for leading electrical oscillations generated therein out of said device.

3. An electron discharge device comprising: a cathode; an anode structure spaced from and concentrically disposed about said cathode; said anode structure including an annular cavity resonator having a central opening defined by a plurality of overlapping electron-receiving anode portions projecting alternately from upper and lower halves of said cavity resonator and lying in the surface of a cylinder; a pair of rings extending from opposite sides of said cavity resonator; cap members closing the outer ends of said rings; means, extending into said cavity resonator, for leading electrical oscillations generated therein out of said device; and means, carried by said cavity resonator and also extending therein, for varying the reactive impedance constants thereof to tune said device to a predetermined frequency of oscillation.

4. An electron discharge device comprising: a cathode; an anode structure spaced from and concentrically disposed about said cathode; said anode structure including an annular cavity resonator having a central opening defined by a plurality of overlapping electron-receiving anode portions projecting alternately from up-

per and lower halves of said cavity resonator and lying in the surface of a pair of rings extending from opposite sides of said cavity resonator; cap members closing the outer ends of said rings; a cylinder; a second cavity resonator carried by and coupled to said first-named cavity resonator; and means, slidably mounted within said second cavity resonator, for altering the reactive impedance constants thereof, and thereby tuning said device to a predetermined frequency of oscillation.

5. An electron-discharge device comprising: a cathode; an anode spaced from said cathode and incorporating a cavity resonator; and a pair of opposed magnetic members disposed, respectively, on opposite sides of said anode to establish a magnetic field therethrough in a direction transverse to the discharge path between said cathode and said anode; each of said magnetic members being of E-shaped cross-section and including a central leg constituting a pole piece of one polarity, and a pair of outer legs of opposite polarity in contact with the outer legs of the other of said magnetic members to complete the path of said magnetic field.

6. An electron-discharge device comprising: a cathode; and an anode structure spaced from said cathode; said anode structure including a base portion having an annular recess therein, an upstanding lip extending from one side of said recess, and a plurality of electron-receiving anode portions projecting from the other side of said recess; a ring extending from the side of said base portion opposite said lip and anode portions; a cap member closing the outer end of said ring; and a cathode lead electrically connected to said cathode and extending exteriorly of said device through said ring; said cathode lead lying in a plane intermediate said anode structure and said cap.

7. An electron-discharge device comprising: a cathode; and an anode structure spaced from said cathode; said anode structure including a pair of base portions each of which has an annular recess therein, an upstanding lip extending from one side of each of said recesses, and a plurality of electron-receiving anode portions projecting from the other side of each of said recesses; adjacent electron-receiving anode portions overlapping each other and lying in the surface of a cylinder; a ring extending from the

side of each of said base portions opposite said lip anode portions; and a cap member closing the outer end of each of said rings; and a pair of cathode leads electrically connected to said cathode and extending exteriorly of said device through said rings; said cathode leads lying in planes intermediate said anode structure and said caps.

8. An electron-discharge device comprising: a cathode; an anode structure spaced from said cathode; said anode structure including a pair of base portions each of which has an annular recess therein, an upstanding lip extending from one side of each of said recesses, and a plurality of electron-receiving anode portions projecting from the other side of each of said recesses; adjacent electron-receiving anode portions overlapping each other and lying in the surface of a cylinder; said base portions, together with said lips and said electron-receiving anode portions, defining a cavity resonator; a pair of rings extending from opposite sides of said cavity resonator; cap members closing the outer ends of said rings; a pair of cathode leads electrically connected to said cathode and extending exteriorly of said device through said rings; said cathode leads lying in planes intermediate said anode structure and said cap and means coupled with said cavity resonator for leading oscillations generated therein out of said device.

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

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2,209,923	Kilgore	July 30, 1940
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Number	Country	Date
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Certificate of Correction

Patent No. 2,478,644 August 9, 1949

PERCY L. SPENCER

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 7, line 2, after "a" and before "pair" insert *cylinder; a*; line 5, strike out the words and semicolon "a cylinder;" ; column 8, line 2, for "anode portions; and a" read *and anode portions; a*; line 28, for "cap" read *caps*;

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 10th day of January, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.