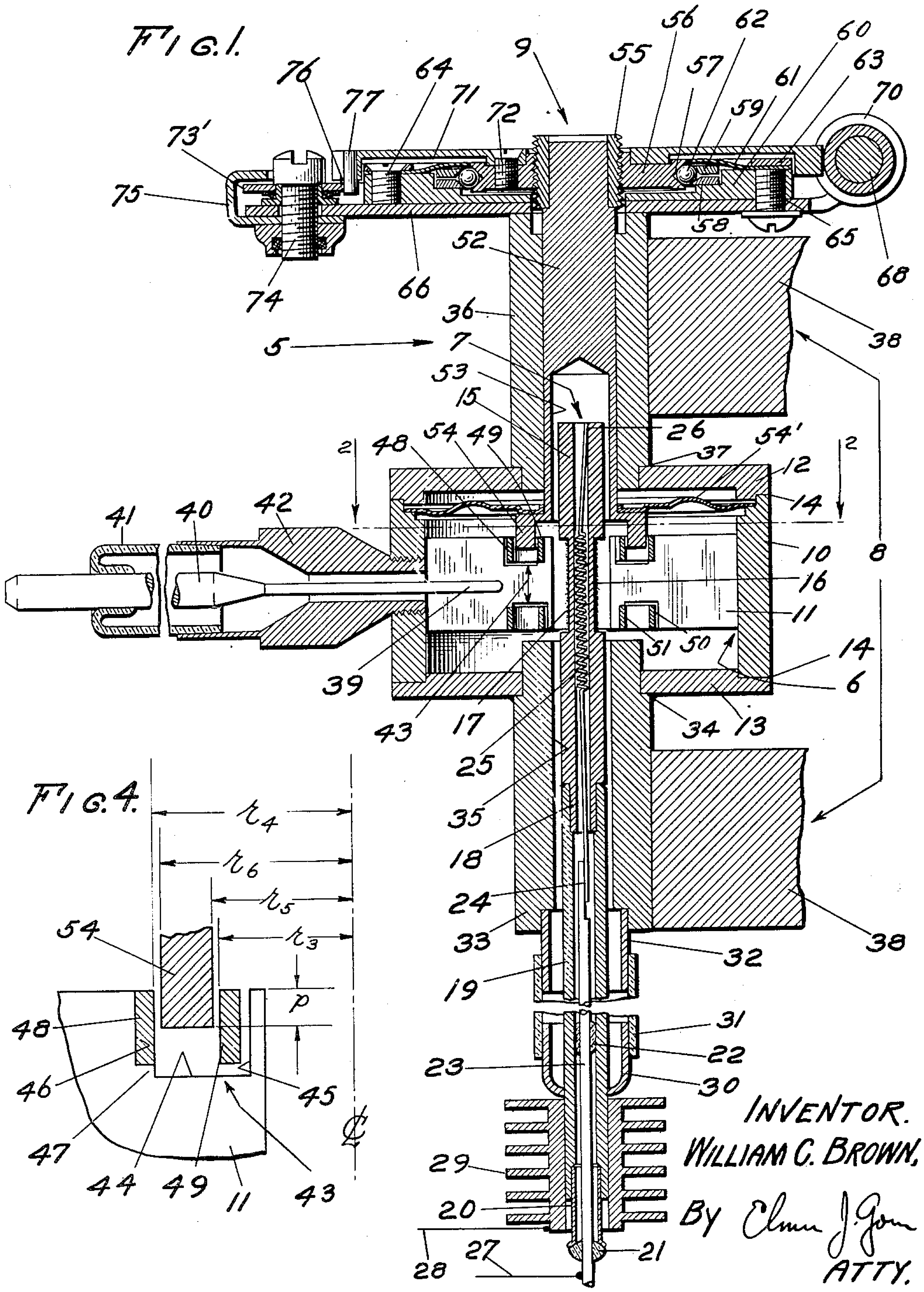
Jan. 6, 1953 W. C. BROWN 2,624,861

ELECTRON DISCHARGE DEVICE OF THE MAGNETRON TYPE

Filed March 19, 1945 2 SHEETS—SHEET 1



INVENTOR.
WILLIAM C. BROWN,
BY Elmer J. Gorn
ATTY.

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FIG. 3.

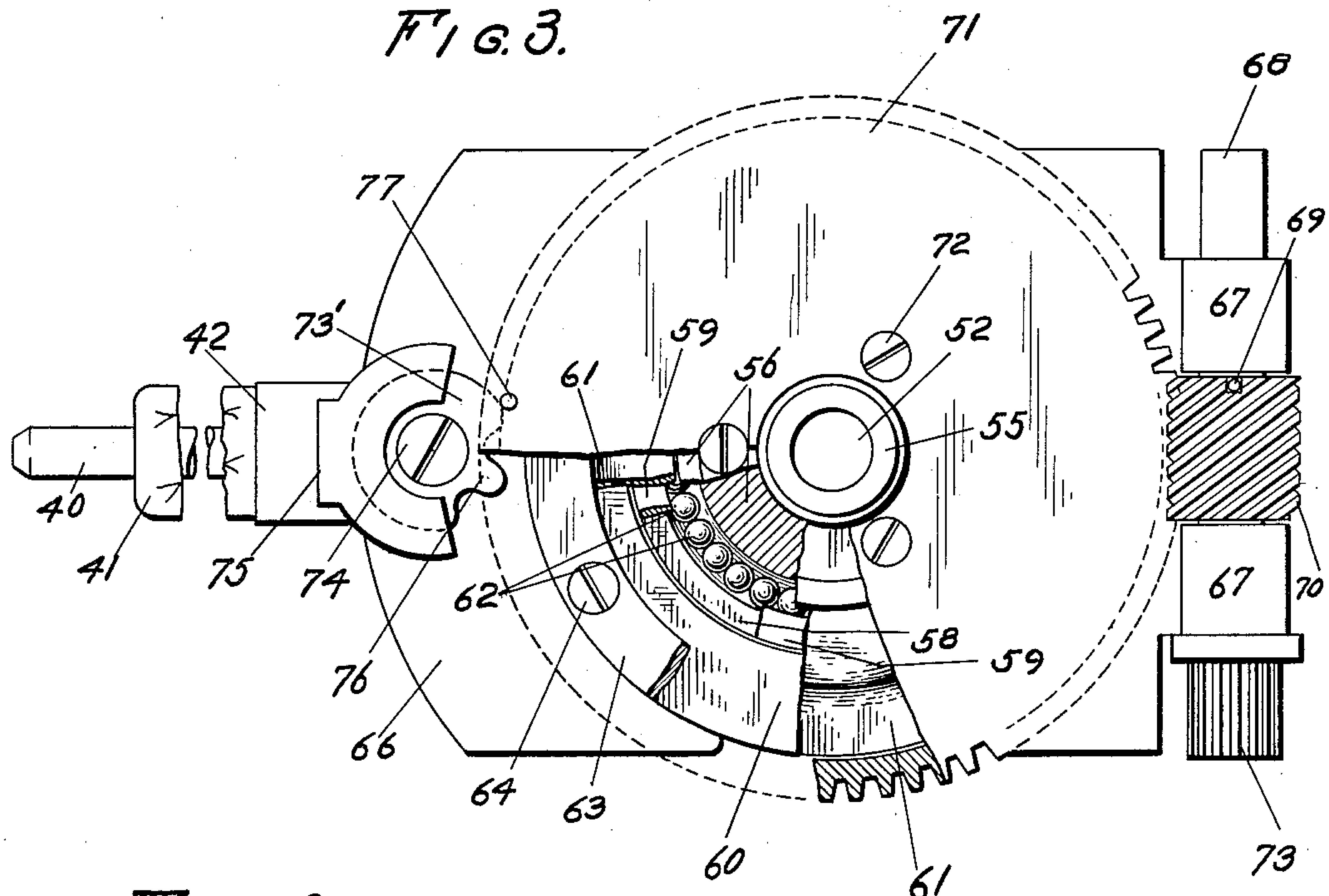
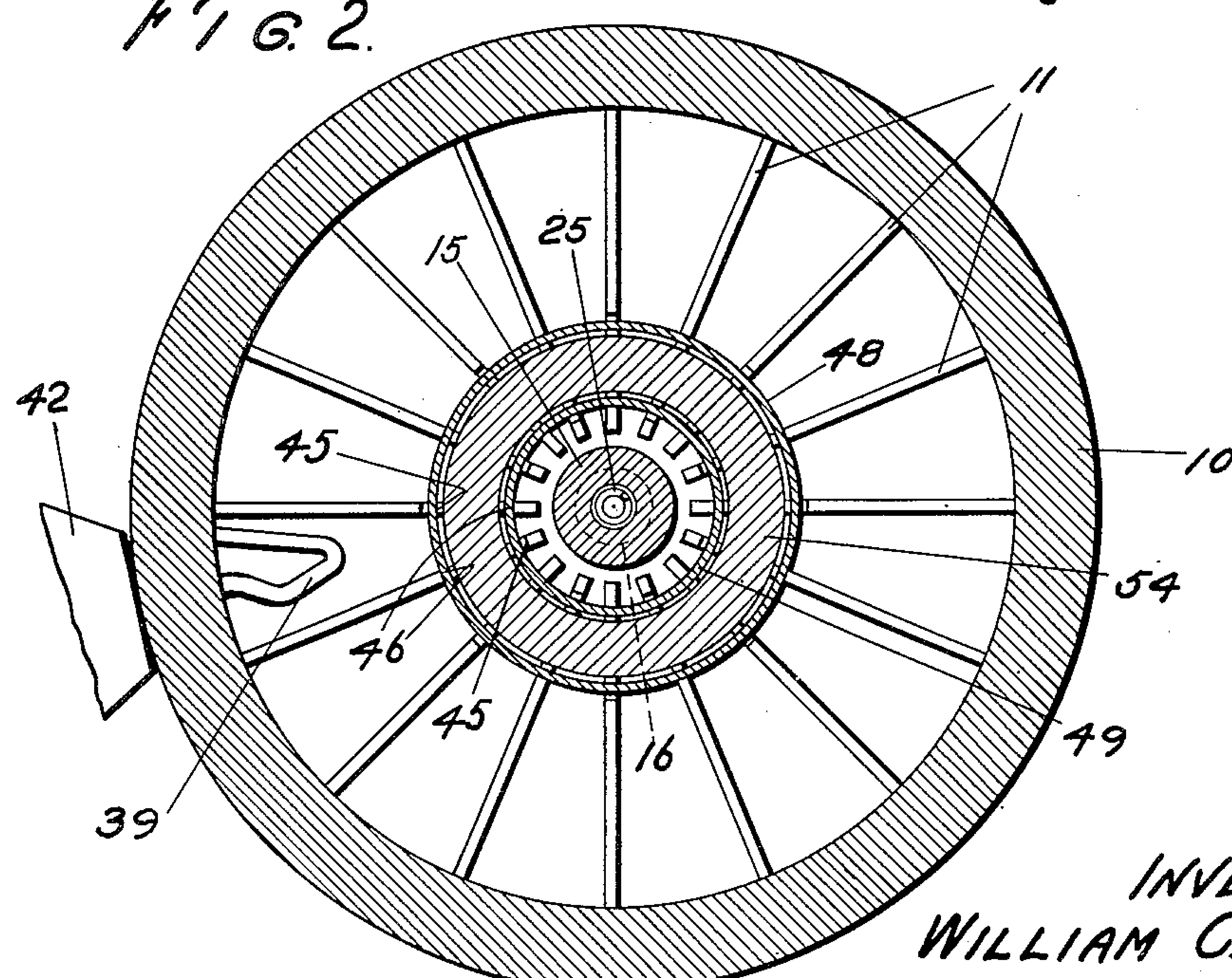


FIG. 2.



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ATTY.

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ELECTRON DISCHARGE DEVICE OF THE MAGNETRON TYPE

William C. Brown, Lincoln, Mass., assignor to Raytheon Manufacturing Company, Newton, Mass., a corporation of Delaware

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My present invention relates to electron-discharge devices, and more particularly to tunable electron-discharge devices.

While not limited thereto, my present invention is especially suitable for tuning electron-discharge devices of the so-called magnetron type.

One of the objects of my present invention is to provide means for tuning an electron-discharge device through a substantial frequency range, and, by "substantial" frequency range, I mean a range in which the maximum frequency deviation represents an appreciable percentage of the natural resonant frequency of the device, for example, at least from about 10% to about 40% of said natural resonant frequency.

Another object of my present invention is to so construct the aforementioned tuning means that the frequency deviation obtained thereby is continuous and substantially linear.

These, and other objects which will become more apparent as the detailed description of my present invention progresses, are attained, briefly, in the following manner.

As above indicated, my present invention is especially suitable for tuning an electron-discharge device of the magnetron type. I prefer that said device include an anode structure, made of highly conductive material, such as copper, and comprising a cylindrical body provided with a plurality of interiorly-extending, radially-disposed anode members, each adjacent pair of said anode members, together with that portion of said cylindrical body lying therebetween, constituting a cavity resonator.

I provide said anode structure with at least one pair of conducting straps alternately contacting successive anode members, the straps of each pair being so disposed with respect to each other as to present a capacitance therebetween, said capacitance, together with the capacitance and inductance built into the device as a function of the geometry thereof, determining the natural resonant frequency at which the device normally operates.

I further provide the device with another conducting member, which is adapted to be introduced into the space between the straps of at least one of the above-mentioned pairs thereof, the introduction of this conducting member so altering the above referred to inter-strap capacitance, and adding such other capacitance, as to thereby enable the tuning of the device to a frequency other than its natural resonant frequency.

I have found that by such means I am able to obtain a substantial frequency deviation, which is continuous and linear.

In the accompanying specification I shall describe, and in the annexed drawings show, an illustrative embodiment of the electron-discharge devices of my present invention. It is, however,

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to be clearly understood that I do not wish to be limited to the details herein shown and described for purposes of illustration only, inasmuch as changes therein may be made without the exercise of invention, and within the true spirit and scope of the claims hereto appended.

In said drawings,

Fig. 1 is a longitudinal sectional view taken substantially through the center of a tunable magnetron made in accordance with the principles of my present invention;

Fig. 2 is a transverse enlarged sectional view taken along line 2—2 of Fig. 1;

Fig. 3 is a top plan view of the device shown in Fig. 1, partially broken away more clearly to show the inner construction of one form of tuning drive which may be used therein; and

Fig. 4 is an enlarged, fragmentary view of one of the anode members of the device shown in Fig. 1, illustrating the physical relationship between said anode member and the above-described tuning means.

Referring now more in detail to the aforesaid illustrative embodiment of my present invention, and with particular reference to the drawings showing the same, the numeral **5** generally designates an electron-discharge device of the so-called magnetron type. Said device comprises an anode structure **6**, a cathode structure **7**, magnetic means **8** for establishing a magnetic field in a direction perpendicular to the path of the electron-flow between said cathode and anode structures, and tuning means **9**.

In the device shown, the anode structure **6** includes a cylindrical body **10** made of highly conductive material, such as copper, said body being provided with a multiplicity, here shown as sixteen, of radially-disposed, interiorly-extending anode members in the form of vanes **11**, each adjacent pair of said vanes, together with that portion of said cylindrical body lying therebetween, constituting a cavity resonator whose natural resonant frequency is, as is well known in the art to which my present invention relates, a function of the geometry of the physical elements making up the same. I shall further describe the anode members **11** when referring, in a later portion of this specification, to the details of the tuning means **9**.

The anode structure is closed at its ends, for example, by end plates **12** and **13**, with the junctions between the cylindrical body **10** of said structure, and said plates **12** and **13**, hermetically sealed, as at **14**.

The cathode structure **7**, which is coaxial with the anode structure **6**, includes a cathode sleeve **15**, conventionally made of nickel, or the like, provided with a reduced portion **16** whose length, preferably, is coextensive with the width of the anode members 11, said reduced portion 16 being provided with a highly electron-emissive coating 17, for example, of the well known alkaline-earth metal oxide type.

In order properly to support the cathode sleeve 15 with respect to the anode members 11, said sleeve may be reduced, as at 18, to fit into an elongated, electrically-conductive tubular member 19 having, at its outer end, a ferrule 20 closed by a glass seal 21. Said seal, together with one or more glass beads 22 disposed within the tubular member 19, supports a lead-in conductor 23 which passes through said member 19 and has its upper end connected, as at 24, to one terminal of a cathode heating filament 25. The other terminal of said filament may be connected, as at 26, to the cathode sleeve 15.

In order to convey current to the filament 25, the lead-in conductor 23 is connected by a conductor 27 to one terminal of a suitable source of voltage (not shown), the other terminal of said source of voltage being connected by a conductor 28 to a heat-dissipating member 29 fixed upon the lower end of the tubular member 19.

In order properly to support the cathode 7, and insulate the same from the anode structure 6, the tubular member 19 may have fixed thereto a cup-like bushing 30 sealed into one end of a glass tube 31, the other end of said glass tube having sealed therein a tubular bushing 32, in turn, secured to a tubular pole piece 33, constituting one of the components of the magnetic means 8.

Said pole piece 33 may be hermetically sealed, as at 34, into the end plate 13, and be provided with a central bore 35 whereby the cathode structure 7 may enter the device.

Another tubular pole piece 36 may be hermetically sealed, as at 37, into the end plate 12, said pole piece and the pole piece 33 being fixed, for example, to the opposite ends of a horseshoe magnet 38 (only partially shown), whereby an appropriate magnetic field may be established, as previously indicated, in a direction perpendicular to the path of the electron-flow between the cathode structure 7 and anode structure 6.

Now, by suitably heating the cathode, and applying a proper potential difference between said cathode and the anode, the device can be made to generate electrical oscillations of a wave length determined, primarily, by the capacitance and inductance built into said device as a function of the geometry thereof, and more especially, of the dimensions of the above referred to cavity resonators defined by the anode structure.

In order to extract power from the device I may, for example, introduce a loop 39 into one of said cavity resonators, said loop coupling with the magnetic component of the above-mentioned electrical oscillations. Said loop may, in turn, be connected to a conductor 40 supported in a glass seal 41 fused into an outlet pipe 42, said pipe being threaded and hermetically sealed into the cylindrical body 10 of the anode structure 6.

In the device as thus far described, there is no external control over the frequency of the generated oscillations and, furthermore, because of the numerous paths which the oscillating energy can follow within the anode structure of said device, spurious oscillations are present which reduce the efficiency of the device.

In order to eliminate these disadvantages, I proceed as follows.

Each anode member 11 is provided, preferably, in both its upper and lower edges, adjacent its inner end, with cut-away portions or slots 43, each slot being defined by a straight bottom edge 44, a straight side edge 45, and a shouldered side edge 46, the shoulder being designated by the reference character 47. Said upper and lower slots are laterally reversed with respect to each other, whereby the straight side edge 45 of one of said slots, say, the upper slot in the particular anode member 11 being described, is in substantial alignment with the shouldered side edge 46 of the lower slot in said anode member, and the shouldered side edge 46 of said upper slot is in substantial alignment with the straight side edge 45 of said lower slot.

By so forming each anode member 11, and inverting adjacent members with respect to each other, a single type of element can be utilized for all of said anode members.

I now provide an annular conducting member or strap 48, which seats upon all of the shoulders 47 of the side edges 46 of the upper slots 43 in alternate anode members 11, said strap clearing the straight side edges 45 in the adjacent, inverted anode members. I also provide a similar, but smaller-diameter strap 49, which seats upon the shoulders 47 of the side edges 46 of the upper slots in said adjacent, inverted anode members, said strap 49 clearing the straight side edges 45 in said first-mentioned, alternate anode members.

The straps 48 and 49 are thus concentrically disposed with respect to each other, and present a capacitance therebetween which enters into the determination of the natural resonant frequency of the device.

The lower slots 43 in the anode members 11 may, if desired, also be provided with concentrically disposed straps 50 and 51, and if such straps are provided, they, too, enter into the determination of the natural resonant frequency of the device.

It has been found that, when alternate anode members are electrically inter-connected as just described by the straps 48 to 51, inclusive, the spurious oscillations above-referred to become suppressed.

Now, I have found that, inasmuch as the straps of each pair thereof have a capacitance therebetween, they may be considered the plates of a capacitor, and, by varying said capacitance and introducing additional capacitance in parallel therewith, the device can be tuned, and, to this end, I proceed as follows.

A plunger 52, made of highly conductive material, such as copper, is slidably mounted in the bore of the tubular pole piece 36, the inner end of said plunger being recessed, as at 53, to accommodate the upper end of the cathode structure 6, and the extremity thereof being cupped to provide a conducting annulus 54, which, when moved, for example, intermediate the straps 48 and 49, constitutes, together with said straps, a variable capacitor. In order to maintain the device air-tight, I provide an apertured flexible diaphragm 54′, hermetically sealed, at its periphery, to the cylindrical body 10 of the anode structure 6, and similarly sealed, at its central aperture, to said plunger 52.

The introduction of the annulus 54 into the space between the straps 48 and 49 does two things. First, it reduces the effective area of the surfaces of said straps between which the above-mentioned capacitance exists, but, inasmuch as this capacitance is small to begin with, the overall effect on the frequency of the device is, likewise, small. Second, it forms, together with said straps, two capacitors, connected in series, which did not, before, exist. Inasmuch as the gaps between said annulus and said straps are small, the total capacitance of the newly formed capacitors is relatively large, and this capacitance, added in parallel with what remains of the original capacitance, has a considerable effect upon the frequency of the device.

The variation in capacitance which may be brought about by a tuning mechanism of the type just described may be calculated by means of the equation:

$$C=C_{tube}+1.41p\left[\frac{1}{ln\frac{r_5r_4}{r_3r_6}}-\frac{1}{ln\frac{r_4}{r_3}}\right]\mu\mu f.$$

where C_{tube} represents the unaltered or original capacitance built into the device as a function of the geometry thereof, and p, and r_3, r_4, r_5, and r_6, are, respectively, the extent of penetration and the radii shown in Fig. 4 of the drawings.

There remains to be described the control mechanism of the tuning means 9, by means of which the penetration of the annulus 54 into the space intermediate the straps 48 and 49 may be varied.

While not limited thereto, I prefer to construct such tuning control means as follows.

Secured on the upper end of the plunger 52 is a threaded bushing 55, engageable in a disk 56 whose periphery may be provided with a V-cut 57, constituting a ball-bearing race. Surrounding said race, is another race comprised of two cooperating bevelled rings 58 and 59, the ring 58 being carried by a disk 60, and the ring 59 being pressed into cooperation with said ring 58 by an annular spring 61. The races are receptive therebetween of bearing balls 62, and the spring 61 is affixed to the disk 60 by a flat retaining ring 63 and bolts 64.

The disk 60 is maintained against rotation by being bolted, as at 65, to a plate 66 fixed, at its center, to the pole piece 36, the plate 66 being provided with bearings 67 in which is journalled a shaft 68. Mounted upon the shaft 68, as by means of a pin 69, is a worm gear 70 engageable with a worm wheel 71 secured to the disk 56 by means of bolts 72. The shaft 68 is provided, at one end, with a pinion 73, whereby the same may be manually or otherwise rotated, slidably to move the plunger 52 with respect to the pole piece 36, and thus vary the capacitances between the straps 48 and 49, and the annulus 54 and said straps.

In order to protect the device against damage which might be caused by excessive movement of the plunger 52, I provide means for limiting the rotation of the worm wheel 71. Such means may comprise a cam 73' pivotally mounted upon a bolt 74 which is fixed in a bracket 75 carried by the plate 66, said cam having a tooth 76 cooperable with a pin 77 carried by the worm wheel 71. The arrangement is such that the first time the pin 77 approaches the cam 73', it engages the tooth 76 thereof and trips the same into the position shown in Fig. 3 of the drawings. As a result, the next time the pin 77 comes around, it abuts the surface of the cam and cannot pass the same. Rotation of the worm wheel in the opposite direction causes a reversed disposition of the cam, thereby limiting said rotation to two revolutions in each direction.

This completes the description of the aforesaid illustrative embodiment of my present invention. It will be noted from all of the foregoing that I have provided relatively simple means for tuning an electron-discharge device, particularly, a magnetron, through an appreciable frequency range, and it will also be noted that the frequency deviation thereby obtained is continuous and linear.

Other objects and advantages of my present invention will readily occur to those skilled in the art to which the same relates.

What is claimed is:

1. A tunable electron-discharge device comprising: an anode structure provided with anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first conductor electrically connected to one anode member of one adjacent pair thereof; a second conductor electrically connected to the remeaning anode member of such adjacent pair thereof; said conductors presenting a capacitance therebetween; and means, movable intermediate said conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

2. A tunable electron-discharge device comprising: an anode structure provided with a plurality of radially disposed anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first arcuate conductor electrically connected to one anode member of one adjacent pair thereof; a second arcuate conductor electrically connected to the remaining anode member of such adjacent pair thereof; said conductors being concentrically disposed with respect to each other and presenting a capacitance therebetween; and means, movable intermediate said conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

3. A tunable electron-discharge device comprising: an anode structure provided with a plurality of radially disposed anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first circular conductor electrically connected to one anode member of each adjacent pair thereof; a second circular conductor electrically connected to the remaining anode member of each adjacent pair thereof; said conductors being concentrically disposed with respect to each other and presenting a capacitance therebetween; and means, movable intermediate said conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

4. A tunable electron-discharge device comprising: an anode structure provided with anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first conductor electrically connected to one anode member of one adjacent pair thereof; a second conductor electrically connected to the remaining anode member of such adjacent pair thereof; said conductors presenting a capacitance therebetween; and a third conductor, movable intermediate said first and second conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

5. A tunable electron-discharge device comprising: an anode structure provided with a plu-

rality of radially disposed anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first arcuate conductor electrically connected to one anode member of one adjacent pair thereof; a second arcuate conductor electrically connected to the remaining anode member of such adjacent pair thereof; said conductors being concentrically disposed with respect to each other and presenting a capacitance therebetween; and a third conductor, movable intermediate said first and second conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

6. A tunable electron-discharge device comprising: an anode structure provided with a plurality of radially disposed anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first circular conductor electrically connected to one anode member of each adjacent pair thereof; a second circular conductor electrically connected to the remaining anode member of each adjacent pair thereof; said conductors being concentrically disposed with respect to each other and presenting a capacitance therebetween; and a third conductor, movable intermediate said first and second conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

7. A tunable electron-discharge device comprising: an anode structure provided with a plurality of radially disposed anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first arcuate conductor electrically connected to one anode member of one adjacent pair thereof; a second arcuate conductor electrically connected to the remaining anode member of such adjacent pair thereof; said conductors being concentrically disposed with respect to each other and presenting a capacitance therebetween; and a third arcuate conductor movable intermediate said first and second conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

8. A tunable electron-discharge device comprising: an anode structure provided with a plurality of radially disposed anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first circular conductor electrically connected to one anode member of each adjacent pair thereof; a second circular conductor electrically connected to the remaining anode member of each adjacent pair thereof; said conductors being concentrically disposed with respect to each other and presenting a capacitance therebetween; and a third circular conductor, concentric with and movable intermediate said first and second conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

9. A tunable electron-discharge device comprising: an anode structure provided with a plurality of anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; each anode member having a slot formed therein; a pair of conductors disposed in said slots and alternately contacting successive anode members; said conductors presenting a capacitance therebetween; and means, movable intermediate said conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

10. A tunable electron-discharge device comprising: an anode structure provided with a plurality of radially disposed anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; each anode member having a slot formed therein; a pair of annular conductors disposed in said slots and alternately contacting successive anode members; said conductors being concentrically disposed with respect to each other and presenting a capacitance therebetween; and means, movable intermediate said conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

11. A tunable electron-discharge device comprising: an anode structure provided with a plurality of anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; each anode member having a slot formed therein, with the slots of alternate anode members in annular register with each other; a pair of conductors disposed in said slots and alternately contacting successive anode members; said conductors presenting a capacitance therebetween; and means, movable intermediate said conductors for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

12. A tunable electron-discharge device comprising; an anode structure provided with a plurality of radially disposed anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; each anode member having a slot formed therein, with the slots of alternate anode members in annular register with each other; a pair of annular conductors disposed in said slots and alternately contacting successive anode members; said conductors being concentrically disposed with respect to each other and presenting a capacitance therebetween; and means, movable intermediate said conductors for altering said inter-conductor capacitance and connecting, in prising: an anode structure provided with a

13. A tunable electron discharge device comprising: an anode structure provided with a plurality of anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; each anode member having a slot formed therein; a pair of conductors disposed in said slots and alternately contacting successive anode members; said conductors presenting a capacitance therebetween; and a third conductor, movable intermediate said first-named conductors, for altering said intermediate capacitance and connecting, in parallel therewith, an additional capacitance.

14. A tunable electron-discharge device comprising: an anode structure provided with a plurality of radially disposed anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; each

anode member having a slot formed therein; a pair of annular conductors disposed in said slots and alternately contacting successive anode members; said conductors being concentrically disposed with respect to each other and presenting a capacitance therebetween; and a third conductor, concentric with and movable intermediate said first-named conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

15. A tunable electron-discharge device comprising: an anode structure provided with a plurality of anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; each anode member having a slot formed therein, with the slots of alternate anode members in annular register with each other; a pair of conductors disposed in said slots and alternately contacting successive anode members; said conductors presenting a capacitance therebetween; and a third conductor, concentric with and movable intermediate said first-named conductors, for altering said inter-conductor capacitance and connecting, in parallel therewith, an additional capacitance.

16. A tunable electron-discharge device comprising: an anode structure provided with a plurality of anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first conductor electrically connected to one anode member of each adjacent pair thereof; a second conductor electrically connected to the remaining anode member of each such adjacent pair thereof; said conductors presenting a capacitance therebetween; and means, movable intermediate said conductors, for altering said interconductor capacitance and connecting, in parallel therewith, an additional capacitance.

17. A tunable electron-discharge device comprising: an anode structure provided with a plurality of anode members; each pair of adjacent anode members, together with that portion of said anode structure lying therebetween, constituting a cavity resonator; a first conductor electrically connected to one anode member of each adjacent pair thereof; a second conductor electrically connected to the remaining anode member of each such adjacent pair thereof; said conductors presenting a capacitance therebetween; and a third conductor means, movable intermediate said first and second-named conductors, for altering said interconductor capacitance and connecting, in parallel therewith, an additional capacitance.

18. A magnetron comprising an anode body having end spaces at the ends thereof and having a cathode cavity with a cathode therein and having cavity resonators extending from one end space to the other and having segments between successive cavity resonators, strap means at one end of said anode body connecting alternate segments, and variable capacity-changing means in proximity to and changeably effective primarily upon said strap means.

19. A magnetron comprising an anode body having end spaces at the ends thereof and having a cathode cavity and cavity resonators extending from one end space to the other and having a cathode in said cathode cavity, said anode body providing segments between successive cavity resonators, strap means connecting alternate segments, said strap means providing and constituting a boundary for an adjacent capacity-forming strap space, and variable capacity-changing means operative in said strap space and being variably effective therein for changing capacitance to the strap boundary.

20. A magnetron comprising an anode body having end spaces at the ends thereof and having a cathode cavity with a cathode therein and having cavity resonators extending from one end space to the other and having segments between successive cavity resonators, straps at one end space, said straps having faces directed toward each other and constituting a capacitance, each strap being connected to alternate segments, and capacity-changing means adjacent to and facing the faces of both said straps and effective to change capacity between said straps.

21. A magnetron comprising an anode body having end spaces at the ends thereof and having a cathode cavity and cavity resonators radiating therefrom and extending from one end space to the other and having a cathode in said cathode cavity, said anode body providing segments between successive cavity resonators, straps at one end space providing strap space therebetween and said strap space being open at an edge of said straps, and capacity-changing means opposed to the opening of said strap space and movable therein for changing the capacity between the straps.

22. A magnetron comprising an anode body having an axial cavity and cavity resonators radiating from the axial cavity, said anode body providing segments between successive cavity resonators, coaxial cylindrical straps at one end of said segments, and capacity-changing means mechanically insertable into and retractable from the space between said cylindrical straps for capacitance control therebetween.

23. A tunable circuit comprising a conductive body divided into a plurality of sections by cavity resonator defining slots, a first conductive member electrically connecting certain of said sections, a second conductive member electrically connecting other of said sections and adjacent said first member, and means for varying the capacitance between said first and second conductive members comprising a third conductive member having a pair of opposite faces each in juxtaposition to a respective one of said first and second conductive members and means for adjusting the position of said third member relative to said first and second members.

24. A magnetron comprising an anode body having end spaces at the ends thereof and having a cathode cavity and cavity resonators extending from one end space to the other and having a cathode in said cathode cavity, said anode body providing segments between successive cavity resonators, strap means connecting alternate segments, said strap means providing an adjacent strap space, and mechanical movable means insertable in said strap space for changing the capacitance therein.

WILLIAM C. BROWN.

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