Feb. 17, 1953 A. D. LA RUE 2,629,069

TUNABLE ELECTRON DISCHARGE DEVICE

Filed Oct. 14, 1948 3 Sheets-Sheet 1

FIG. 1.

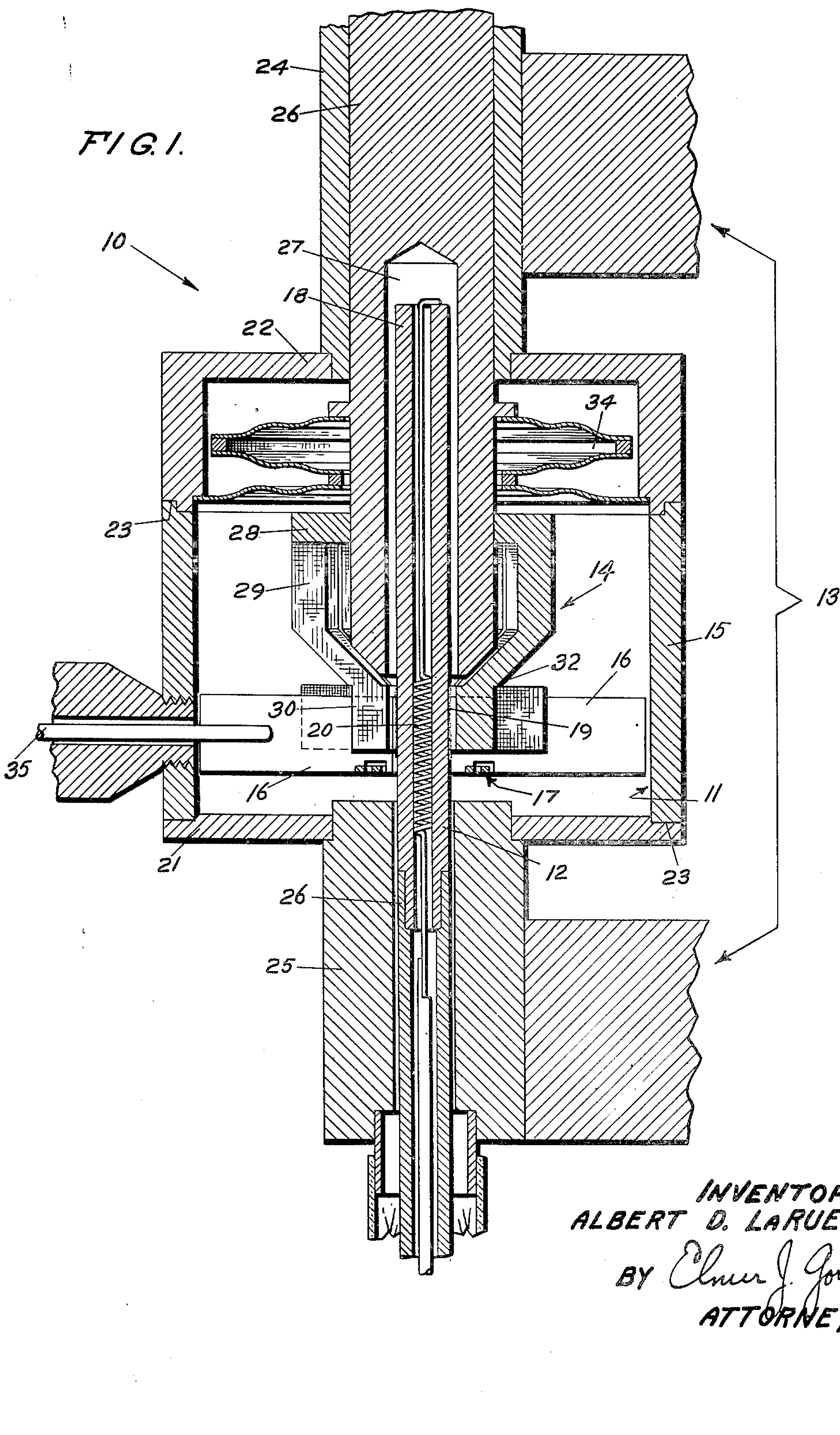

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FIG. 2.

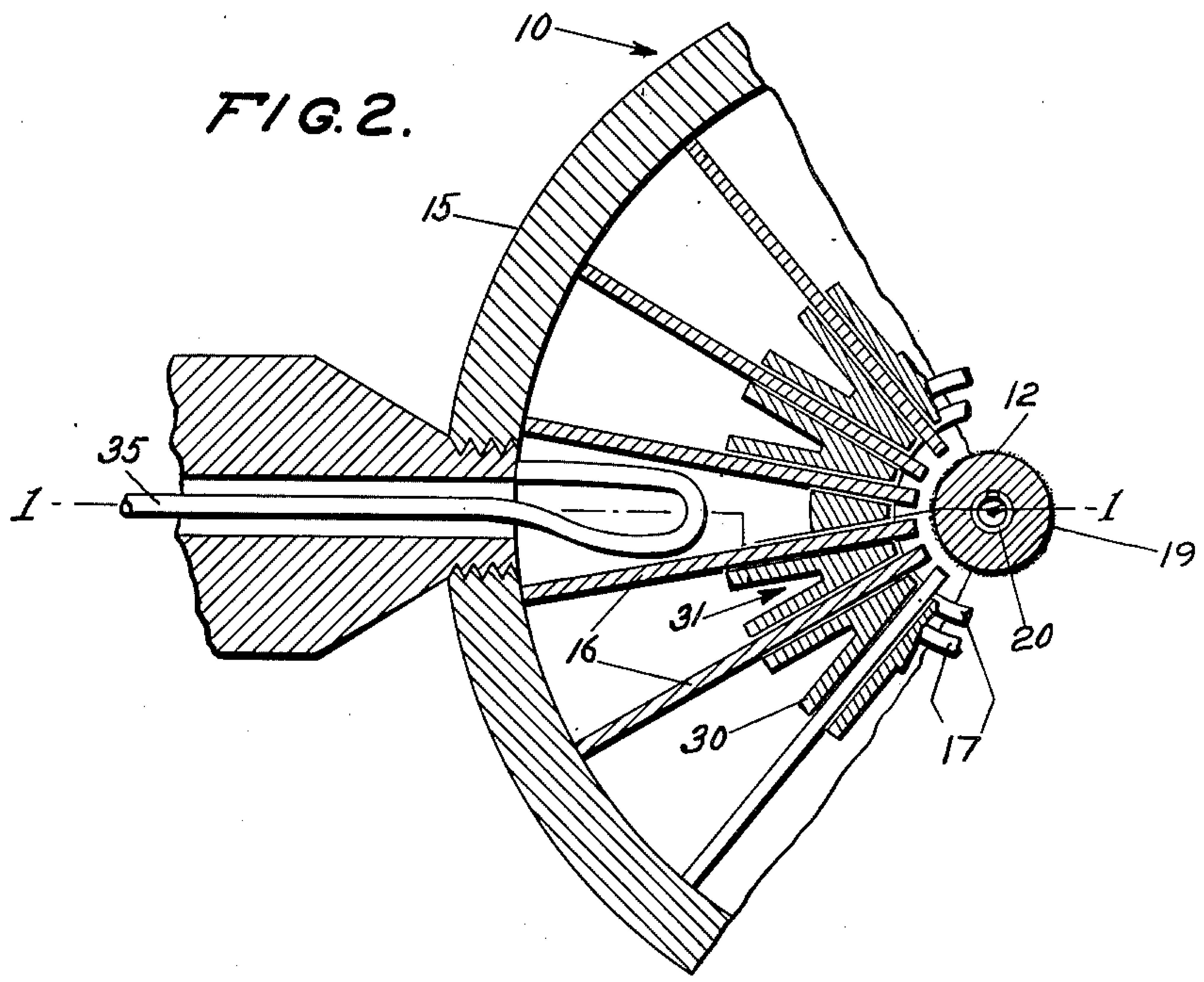
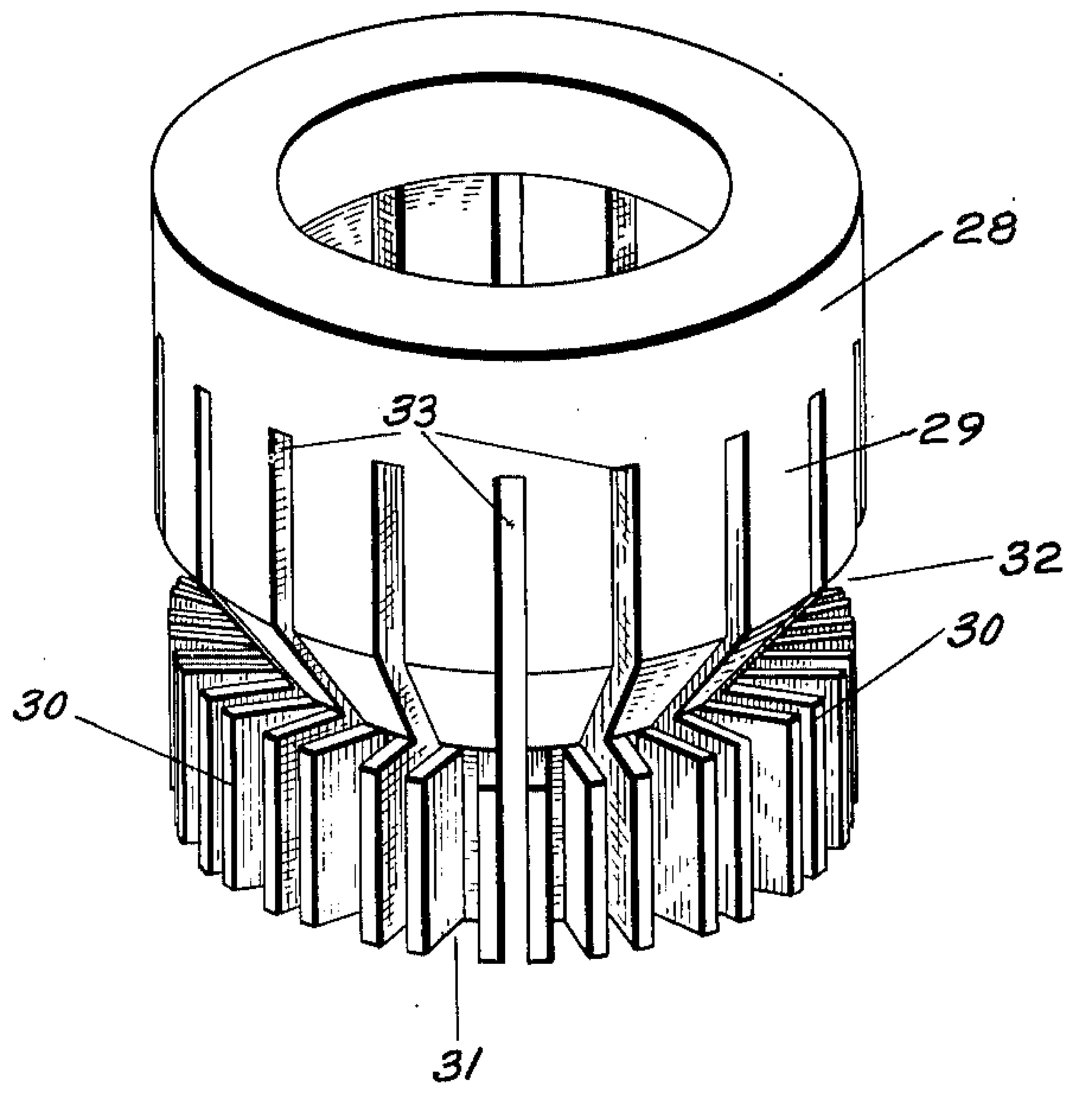


FIG. 3.



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TUNABLE ELECTRON DISCHARGE DEVICE

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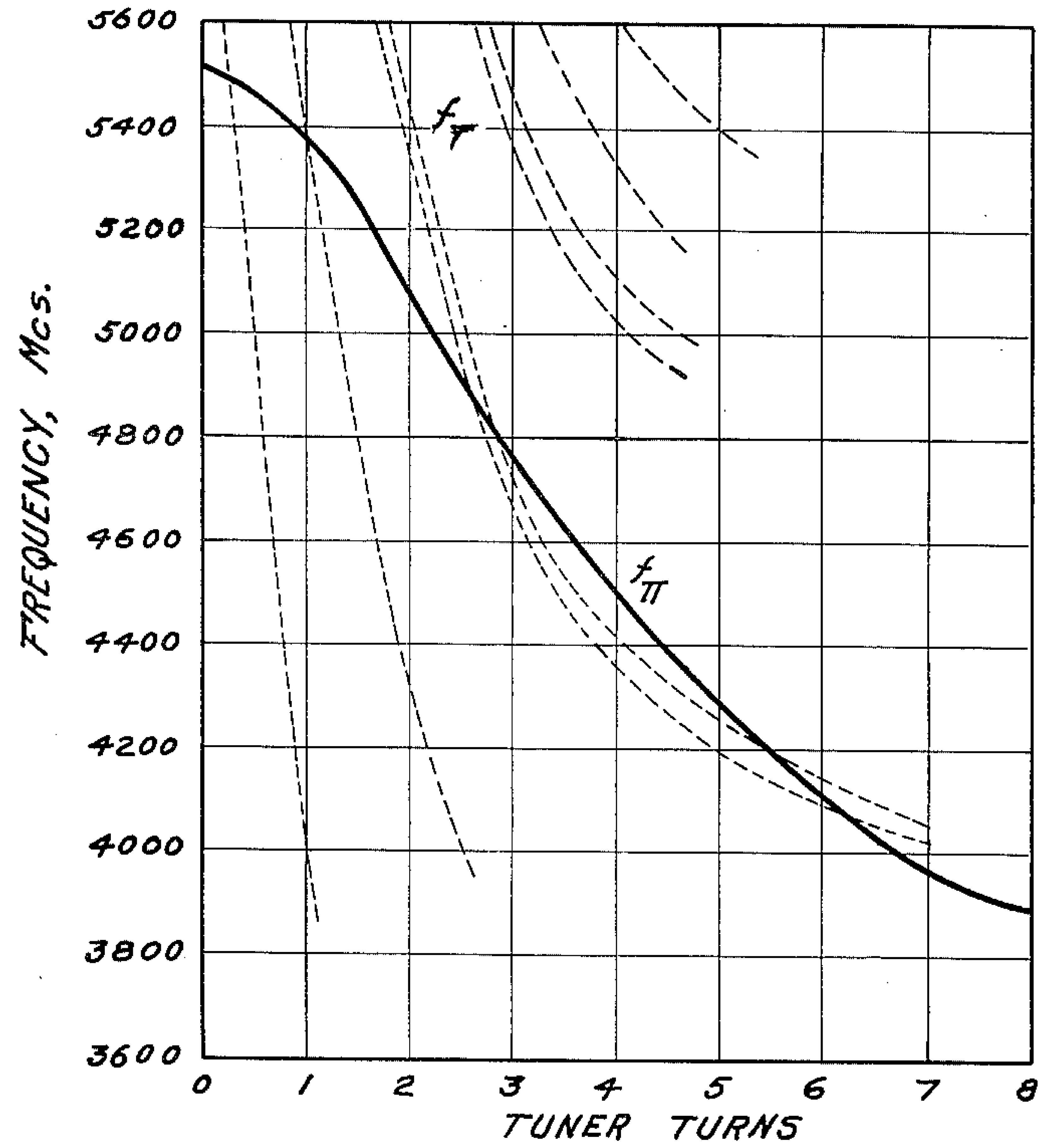

FIG. 4.

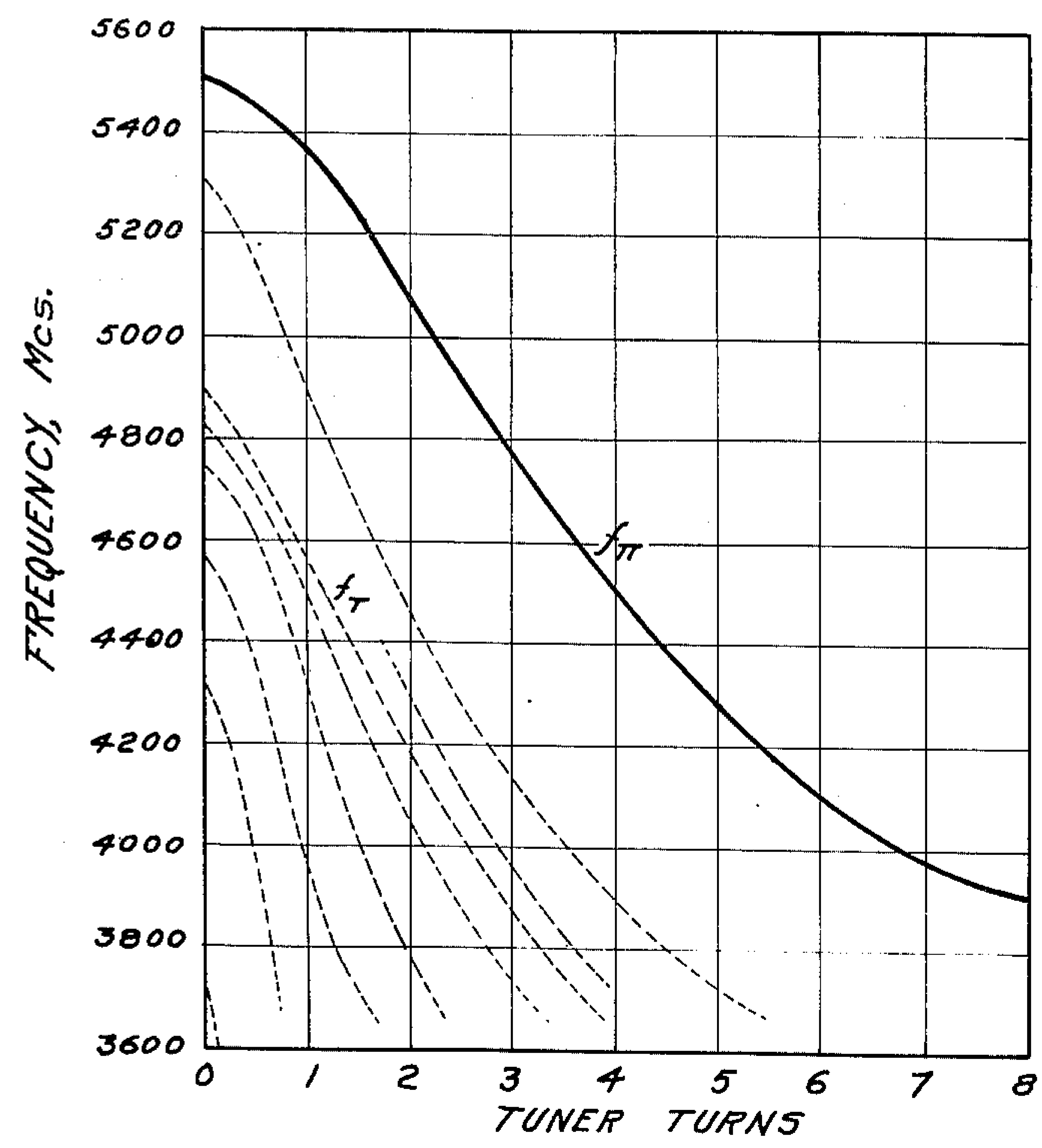

FIG. 5.

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TUNABLE ELECTRON DISCHARGE DEVICE

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Application October 14, 1948, Serial No. 54,540

6 Claims. (Cl. 315—40)

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This invention relates to electron discharge devices, and more particularly to tunable electron discharge devices of the so-called general magnetron type as is set forth in application, Serial No. 668,847.

In prior magnetron designs, tunable over a wide frequency range, resonance conditions are encountered in the magnetron tuning structure which approach the frequency of the desired resonant mode of operation of the magnetron. These parasitic resonant conditions sap power from a desired frequency, thus lowering the efficiency of operation of the tube if, indeed, operation is at all possible, and cause the tuning structure to overheat.

Accordingly, the main object of this invention is to design a magnetron which is free from parasitic resonance interference over a wide frequency range of operation.

A further object of this invention is to design a tuner having low loss characteristics.

Another object of this invention is to design a tuner of rugged construction such as to prevent shorting of the parts.

A further object of this invention is to design a tuner so constructed that the magnetic field may be varied in conjunction with the tuner.

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

A magnetron is constructed according to well-known principles having an anode structure comprising an outer solid conductive ring, a plurality of radially inwardly-extending anode members, each pair of said anode members together with the space included therebetween forming a resonant cavity. Mechanically movable into and out of each of said resonant cavities is a tuning arm which, by varying the capacity in said cavity, varies the resonance thereof and thereby the tuning of the magnetron. The capacity is varied by inserting one of said tuning arms intermediate each pair of anode members at the end of said anode members adjacent the cathode of the device, wherein the capacity of the cavity is the largest. The inductance of the cavity may be varied by inserting a conducting tuning member in the inductive region of the cavity, namely that portion adjacent the outer ring of the anode structure. This produces high losses, however, since the tuning members are inserted in regions of high current, and power losses in the tuning member are proportional to the square

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of the current flow therein. Moreover, if a conductor is inserted in the capacitive region of the cavity and at the same time a conductor is inserted in the inductive region, the resultant change in resonant frequency is small, since, while the capacitance of the cavity is increased, the inductance is decreased, and the tuning effects cancel each other.

Therefore, to obtain a large change in frequency upon insertion of a tuning element into a cavity, and an increased operating efficiency over that obtained in previous designs, substantially all the conducting material of the tuner has been removed in those places where it would approach an inductive region upon insertion into the cavity to be tuned. This results in a substantially V-shaped notch in each tuning element.

It is well known that magnetrons may be tuned by simply tuning their resonant cavity structure, while holding both the magnetic field across the electron discharge path and the potential difference between the cathode and anode constant, but this procedure requires that the magnetron anode current vary with the wavelength of operation.

In order to maintain both voltage and current constant, the magnetic field should be varied in accordance with the relationship.

$$B=\frac{6.7\sqrt{V}Dr_a}{r_a^2-r_c^2}$$

wherein

B=magnetic field applied across the electron discharge path transverse to the direction of motion of the electrons.

V=the potential difference between the anode and cathode structure.

D=Allis' parameter which is dependent on the design of the tube and is substantially proportional to the wavelength of operation of the magnetron, λ.

r_a=radius of the hole in the anode structure concentric with the cathode.

r_c=radius of the cathode.

Since r_a and r_c are fixed by the geometry of the tube, and it is desired to operate with a constant voltage V, the expression reduces to:

B is proportional to D, and since D is proportional to λ, B is proportional to λ, or

$$\frac{B}{\lambda}=K$$

where K is constant.

In order to vary the magnetic flux with the wavelength of operating frequency, a movable magnetic pole is mechanically attached to the tuning structure such that, upon insertion of the tuning structure in the cavities of the cavity resonator, the gap between the movable magnetic pole and a fixed magnetic pole on the opposite side of the electron path is decreased, thereby increasing the magnetic flux applied across the electron path.

The tuning structures in previous designs usually had of themselves resonated at frequencies different from the desired frequency of operation of the magnetron. It was discovered that the resonances of these undesired frequencies were determined by the electrical circuit parameters existing between the tuning elements, and particularly the length of the slots existing between said elements.

Accordingly, the length of said slots was changed in accordance with the present invention so that the tuning structure would resonate at frequencies remote from the desired operating frequency of the magnetron and would not sap off energy from said desired frequency, and, as a result, would permit freedom from tuner resonance interference.

In the accompanying specification there shall be described, and in the annexed drawings shown, an illustrative embodiment of an electron discharge device disclosing the present invention. It is, however, to be clearly understood that the present invention is not to be limited to the details herein shown and described for the 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 the drawings:

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

Fig. 2 is a fragmentary transverse sectional view taken substantially through the center of said magnetron in a plane at right angles to the section plane of Fig. 1 showing a cross-sectional view of the tuner elements, and their relations to the anodes of the tube;

Fig. 3 is an enlarged perspective view of the tuner more clearly showing the relationship of the tuning elements to each other;

Fig. 4 is an experimental set of curves demonstrating how the spurious frequencies cross over the desired frequency in normal magnetron operation; and

Fig. 5 is a set of curves showing operation of the improved design as set forth in this application wherein the spurious frequencies do not interfere with the desired frequency.

Referring now more in detail to the aforementioned illustrated embodiment of the present invention and with particular reference to the drawings illustrating the same, numeral 10 generally designates an electron discharge device of the magnetron type having an anode structure 11, a cathode structure 12, magnetic means 13 for establishing the magnetic field in a direction perpendicular to the direction of electron flow between said cathode and anode structures, and a tuning means 14. In the device shown, the anode structure is of a well-known design including a cylindrical body 15, of conductive material, such as copper, said body being divided to the multiplicity of radially-disposed internally-extending anode members in the form of vanes 16, each pair of adjacent anode members, together with that portion of the cylindrical anode structure included therebetween, defining a resonant cavity.

In order to prevent certain spurious oscillations, alternate anode members are connected together at their inner ends by straps as at 17 to maintain said alternate anode members the same instantaneous potential.

A cathode structure 12 extending through the anode structure, and positioned concentrically therewith, comprises an electron emissive material as at 19, coated on a metal cylindrical rod 18. The cathode structure is heated by a heating element 20 extending through the center of said rod and insulated therefrom, and attached at its upper end to said rod, such that, by applying a potential between said cathode rod and a wire connected with the bottom of said heating element, the cathode may be raised to a suitable temperature for emission of electrons from the coating 19. The magnetron structure is enclosed by the cylindrical body 15 together with end plates 21 and 22 hermetically sealed to said cylinder as at 23. Attached to said end plates are upper and lower magnetic pole pieces 24 and 25 which, in conjunction with the magnetic assembly 13, produce a flux across the cavity of the magnetron. Slidably mounted in the upper pole piece 24 is a rod of magnetic material 26, which may be moved with respect to said fixed pole piece by a mechanical arrangement such as is disclosed in application, Serial No. 668,847. The magnetic rod is hollow at its lower end as at 27, to accommodate the upper end of the cathode structure 12, which is positioned concentrically therewith.

Rigidly attached around, and conforming to the lower end of said magnetic rod, is a tuning structure 14, whereby, when the tuning structure is moved to vary the frequency of operation of the magnetron, the magnetic flux across the gap between the fixed lower pole piece and the movable magnetic rod, which extends the upper pole piece, is also changed, changing the magnetic flux applied across the cavity of the magnetron. As is required for constant voltage and constant current operation, the magnetic flux is increased as the frequency is lowered.

Thus it may be seen that the device will operate over a wide range of frequencies while maintaining a substantially constant anode voltage and current. This is advantageous since the tube may be used in a power supply which is fixed, and, moreover, the problem of gang tuning the power supply voltage with the tuning element is eliminated.

The tuning element proper 14 is comprised of a ring 28 which is rigidly attached to said movable magnetic rod, a plurality of arms 29 extending downwardly from the outer edge of said ring, conforming to but spaced from said movable magnetic rod, and tuning elements 30, which are extensions of said arms extending into the cavities of the cavity resonating structure, and whose upper edges are slightly spaced from the bottom of said movable magnetic pole 26.

Each of said tuning elements 30 comprises a rod having a V-shaped cross section which is inserted in its respective cavity resonator at the inward end of said cavity resonator adjacent the cathode, and with the apex of the V pointing in the direction of said cathode. The legs of the V are positioned adjacent each side of the cavity, so as to produce a maximum effect upon the capacity which exists between each of said adjacent anode members. Between the legs of said V-shaped member there exists a V-shaped notch, which represents material deleted from said tuning element since it added nothing to the capacitive tuning of the element, and, moreover, would act as an inductive tuning element in the region of the cavity where inductive currents become increasingly high with an increase of distance from the cathode. Another notch 32 is formed between the tuning element and the arm which extends downwardly from the ring 28, which also represents material deleted to decrease inductive action of said tuner. This inductive action or tuning is undesirable since it tends to counteract the change in frequency produced by the tuning elements in the capacitive region of the cavity.

The arms which support the tuning elements are spaced from movable rod 26 to prevent shorting therewith at their lower ends, and are spaced from each other by slots 33. In previous tunable magnetrons, these slots extended just far enough into the tuning structure to accommodate the anode members governed by considerations of rigidity of the structure and conduction of heat away from the tuning element.

However, as stated previously, applicant has discovered that the length of these slots are critical in determining the frequencies or independent resonances of the tuner structure, which, apart from the anode cavities, resonate in a manner similar to that of the well-known unstrapped magnetron.

In general, these resonances will tune in frequency as the tuning members are inserted into the magnetron resonant cavity structure, and the general case is that one or more points of frequency coincidence will occur, where one of the tuner resonances is tuned to the same frequency as that at which the magnetron itself is operating, thus sapping power therefrom.

In Fig. 4 there is shown an experimental set of curves for a magnetron of previous design, wherein the scale, labelled tuner turns, represents the mechanical number of turns of a thread attached to the movable rod to produce a predetermined amount of lateral motion in said rod, as a base for curves showing the frequency change in megacycles. The curve F_π, represents the frequency of operation of the cavity resonator of the magnetron over this range. The dotted curves generally designated as F_t represent curves of the resonant conditions for the various modes of the tuner. Since this tuner resonates as an unstrapped magnetron, conditions for resonance for all of these curves occur at the same time in the magnetron. However, if the frequencies of the tuner resonances may be separated from those through which the magnetron tunes so that no points of coincidence occur and so that no coupled-circuit effects are present, the magnetron will operate and tune throughout the tuning range as if the tuner resonances were not present.

Experimental data of Fig. 4 shows that the tuner resonance curves labelled F_t cross the π mode or desired mode of operation of the magnetron at several points.

Fig. 5 shows curves of operation of the various resonance modes of the improved design of the magnetron wherein all of the resonance curves of the tuner have been shifted, in this case lowered to below F_π, so that the curve of the highest frequency tuner resonance is below the normal mode of operation of the magnetron. Experimental data shows that, under this condition, no energy is sapped off by the tuner resonances.

This lowering of the family of curves of the resonant modes of the tuner structure is accomplished by lengthening the slots 33, since all the resonant modes of the tuner vary as a function of the length of said slots.

Naturally, in view of the foregoing, the frequency of the modes of resonant operation of the tuner may be lowered by using other configurations than the slots, such as circles, circular holes at the upper ends of slots, square holes at the upper ends of slots, or other configurations.

The cathode structure is hermetically sealed into the magnetron pole piece and insulated therefrom in a well-known manner, for example, as disclosed in application, Serial No. 668,847.

The tuning structure is hermetically and movably sealed into the magnetron by means of a triple diaphragm 34 which operates in an obvious manner and as disclosed and shown in my co-pending application, Serial No. 793,889.

Energy is coupled from the magnetron by means of a probe loop 35 inserted into one of the cavities through a gas-tight insulated seal in a well-known manner.

Thus it may be seen that the electron discharge device may be tuned over a wide range with low losses in the tuner due to the non-resonant condition of the tuner at the operating frequency, and the absence of tuner conducting material in the inductive regions of the cavities, and with optimum efficiency and maximum stability due to variation in magnetic flux in conjunction with frequency change.

This completes the description of the aforesaid illustrative embodiment of the present invention. While there has been herein described a preferred form of the invention, other embodiments thereof within the scope of the appended claims will be obvious to those skilled in the art from a consideration of the form shown and the teachings thereof.

What is claimed is:

1. An electron discharge device comprising an anode structure and a cathode adjacent said structure, said anode structure defining a cavity resonator having a plurality of cavities, a tuning structure movably positioned with respect to said cavity resonator, an element of said tuning structure extending into each cavity of said cavity resonator, said elements being separated from each other by slots, and the length of said slots being appreciably greater than an electrical quarter wavelength of the resonant frequency of said cavity resonator.

2. An electron discharge device comprising an anode structure and a cathode adjacent said structure, said anode structure defining a cavity resonator having a plurality of cavities, a tuning structure movably positioned with respect to said cavity resonator, an element of said tuning structure extending into each cavity of said cavity resonator, said elements being separated from each other by slots, and the length of said slots being appreciably greater than an electrical quarter wavelength of the resonant frequency of said cavity resonator, said tuning element comprising a rod having a V-shaped cross-sectional area, and positioned in the high capacity area of said cavity adjacent the cathode, and having the apex of the V pointed toward the cathode.

3. An electron discharge device comprising an anode structure and a cathode adjacent said structure, said anode structure defining a cavity

resonator having a plurality of cavities, a tuning structure movably positioned with respect to said cavity resonator, an element of said tuning structure extending into each cavity of said cavity resonator, said elements being separated from each other by slots, and the length of said slots being appreciably greater than an electrical quarter wavelength of the resonant frequency of said cavity resonator, means for varying the magnetic flux in said cavity resonator comprising a rod of magnetic material movable with respect to said cavity resonator, and positioned adjacent thereto and means connected to said tuning structure for moving said rod in conjunction with said tuning structure, for varying the magnetic flux applied across the electron path of said discharge device, with variations in the resonant frequency of said cavity resonator.

4. An electron discharge device comprising an anode structure and a cathode adjacent said structure, said anode structure defining a cavity resonator having a plurality of cavities, a tuning structure movably positioned with respect to said cavity resonator, an element of said tuning structure extending into each cavity of said cavity resonator, said elements being separated from each other by slots, and the length of said slots being appreciably greater than an electrical quarter wavelength of the resonant frequency of said cavity resonator, means for varying the magnetic flux in said cavity resonator comprising a rod of magnetic material movable with respect to said cavity resonator, and positioned adjacent thereto and means connected to said tuning structure for moving said rod in conjunction with said tuning structure, for varying the magnetic flux applied across the electron path of said discharge device, with variations in the resonant frequency of said cavity resonator, said tuning element comprising a rod having a V-shaped cross-sectional area, and positioned in the high capacity area of said cavity adjacent the cathode, and having the apex of the V pointed toward the cathode.

5. An electron discharge device comprising an anode structure having a plurality of anode members, a cathode, said anode structure defining a cavity resonator, and a tuning structure having a plurality of tuning elements extending into said resonator, the length of the shortest conductive path between the tips of adjacent of said anode members being shorter than the length of the shortest conductive path between the tips of adjacent of said tuning elements.

6. An electron discharge device comprising an anode structure having a plurality of anode members, a cathode, said anode structure defining a cavity resonator, a tuning structure having a plurality of tuning elements extending into said resonator, the length of the shortest conductive path between the tips of adjacent of said anode members being shorter than the length of the shortest conductive path between the tips of adjacent of said tuning elements whereby adjacent elements of said tuning structure present a capacitive impedance at the resonant frequency of said resonator, and means adjacent said device for producing a magnetic field in the region adjacent the tips of said anode members in a direction transverse to the direction of motion of electrons in said region.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,450,629	Bondley	Oct. 5, 1948
2,495,744	Litton	Jan. 31, 1950
2,496,887	Nelson	Feb. 7, 1950
2,498,763	McNall	Feb. 28, 1950
2,508,576	Kusch	May 23, 1950