

July 8, 1947.

C. E. FAY
HIGH POWER ELECTRONIC DISCHARGE DEVICE FOR GENERATING
ULTRA-HIGH FREQUENCY RADIATIONS
Filed Dec. 31, 1942

2,423,443

3 Sheets-Sheet 1

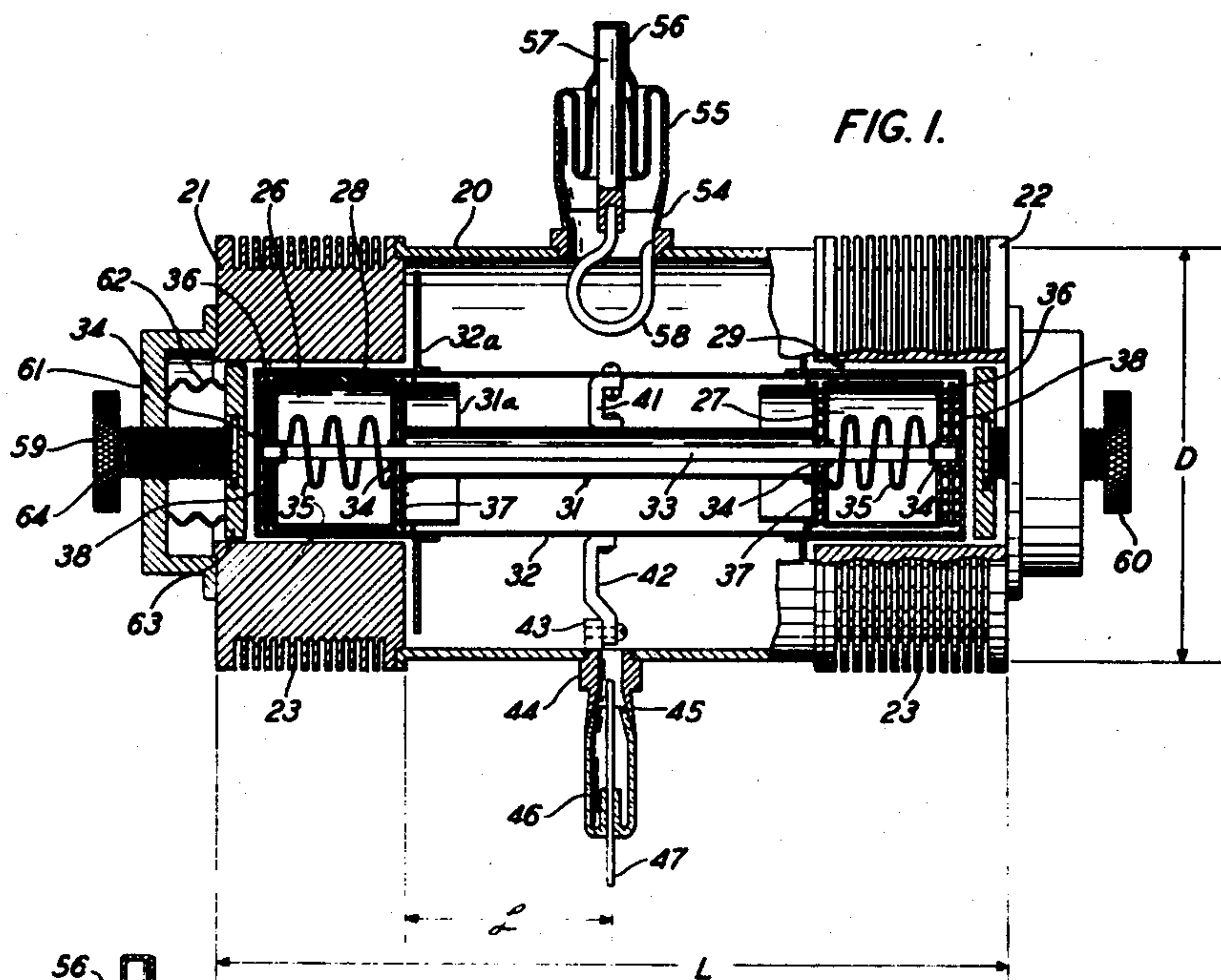


FIG. 1.

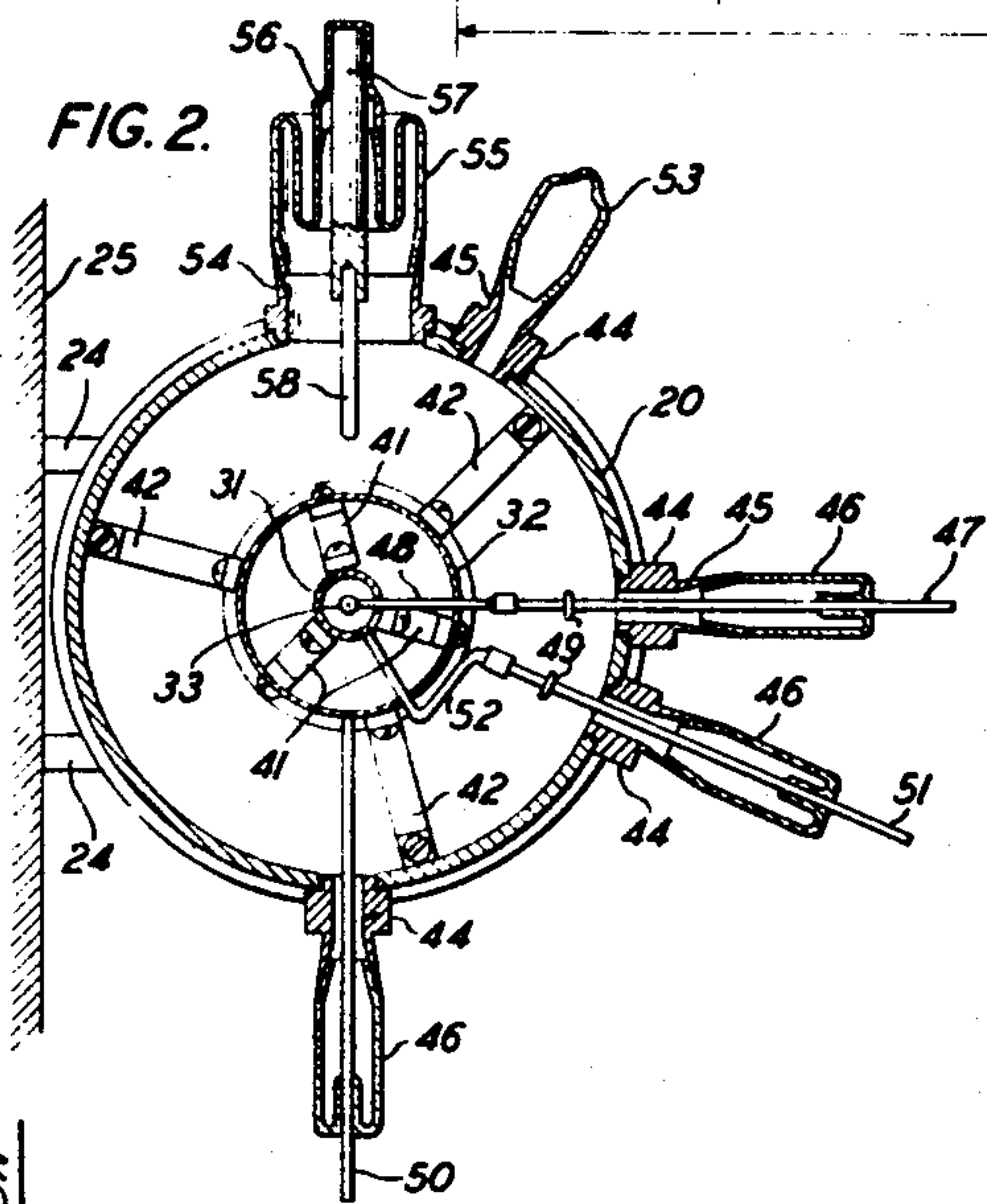


FIG. 2.

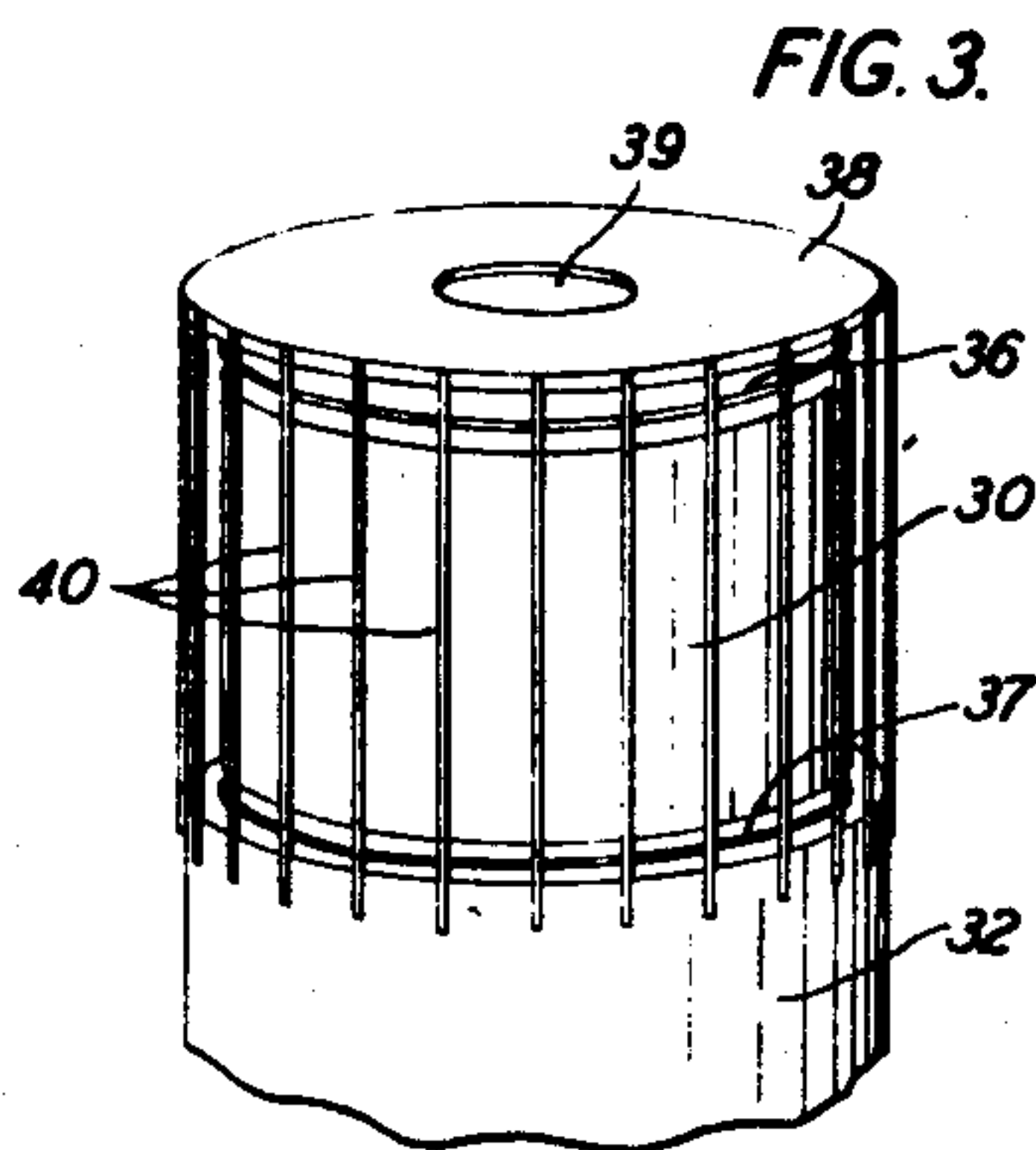


FIG. 3.

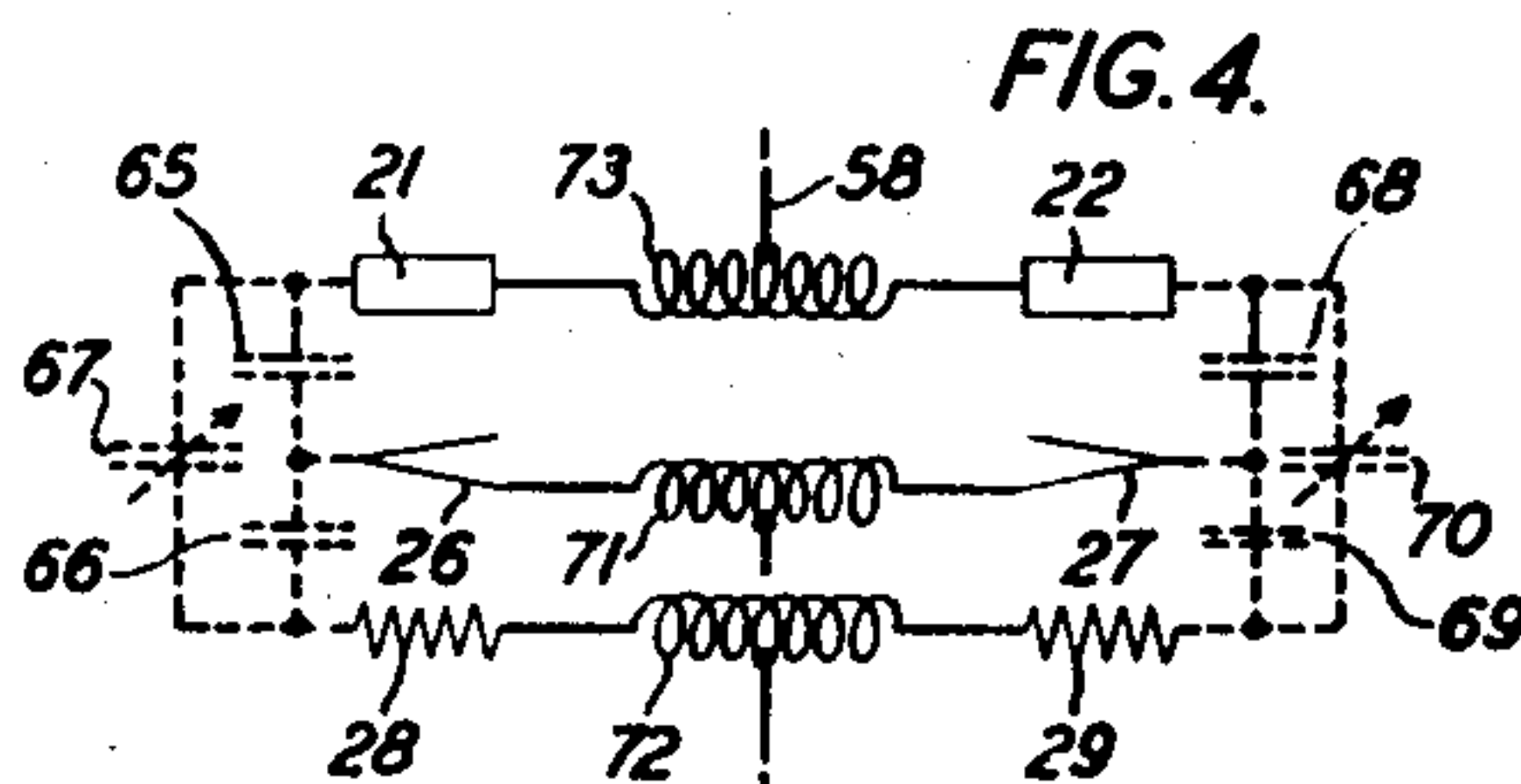


FIG. 4.

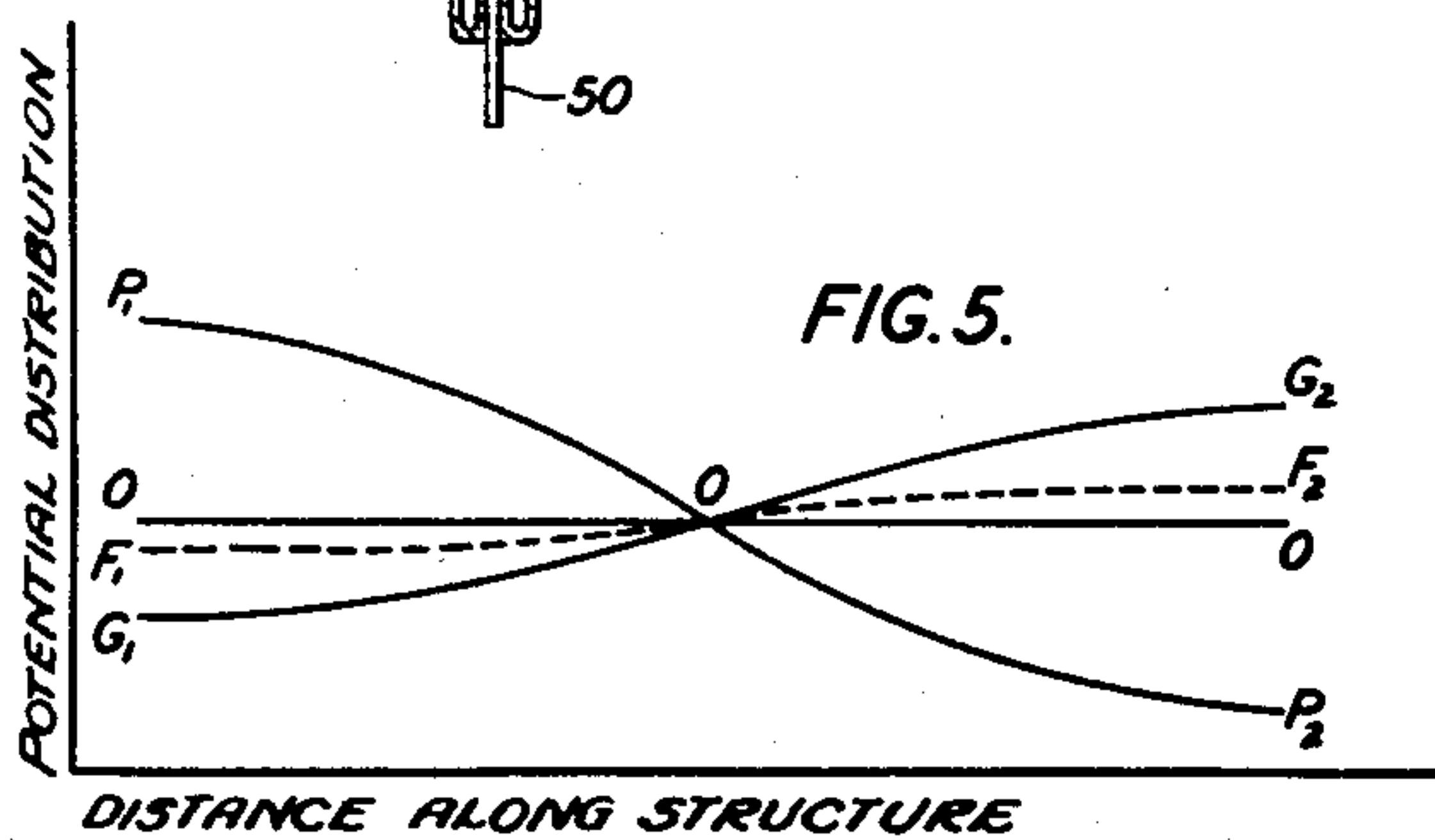


FIG. 5.

INVENTOR
C. E. FAY

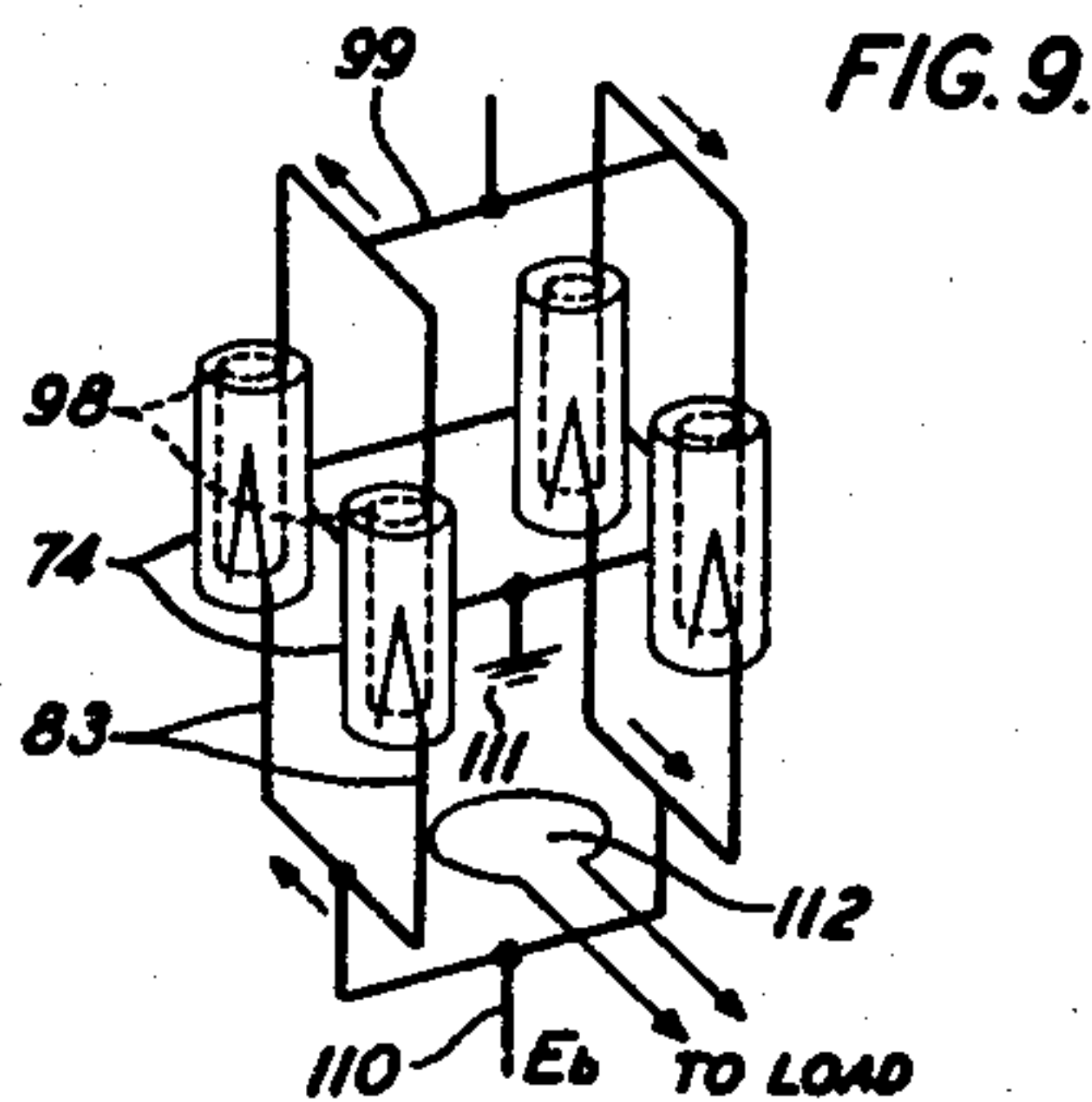
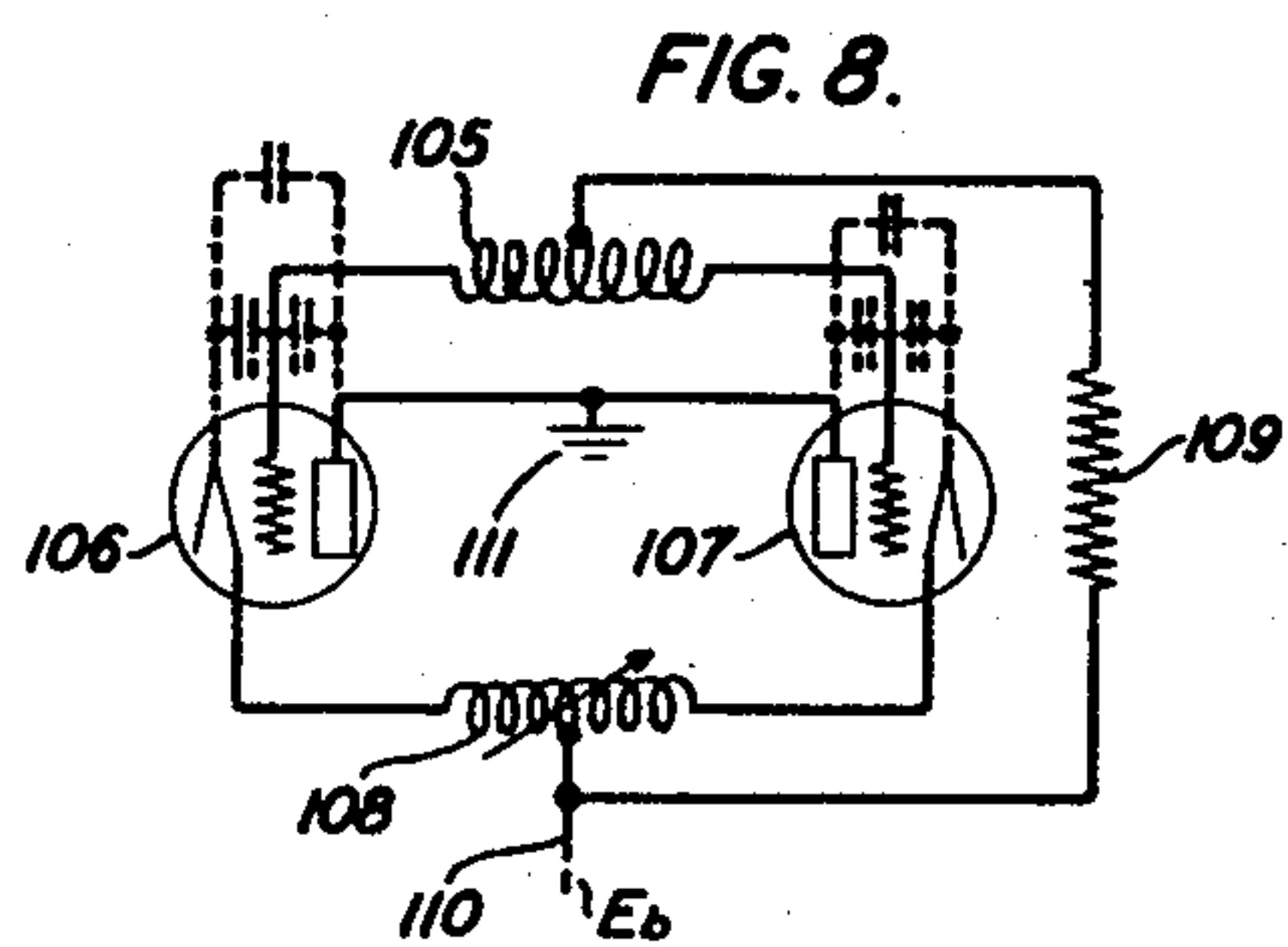
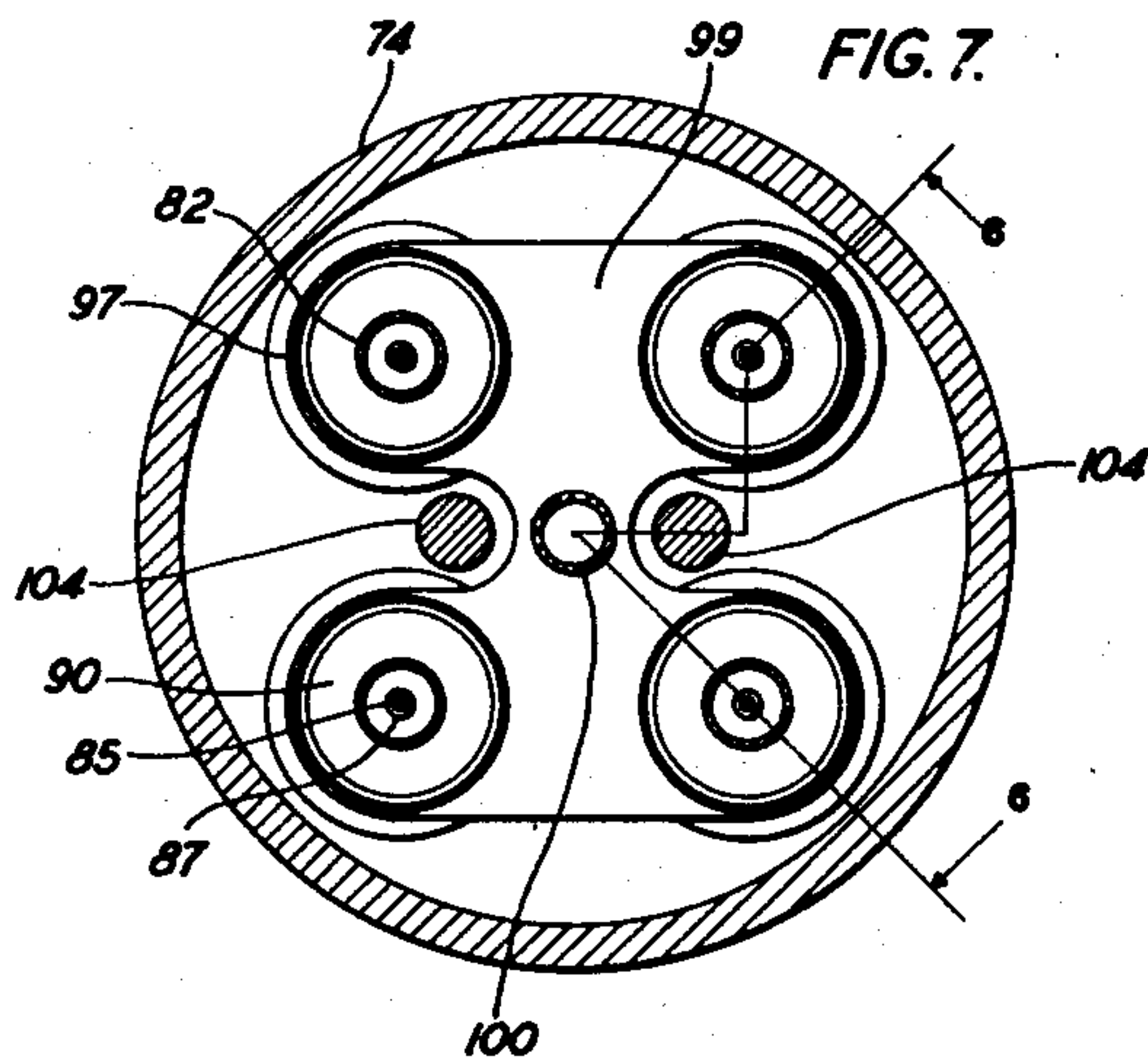
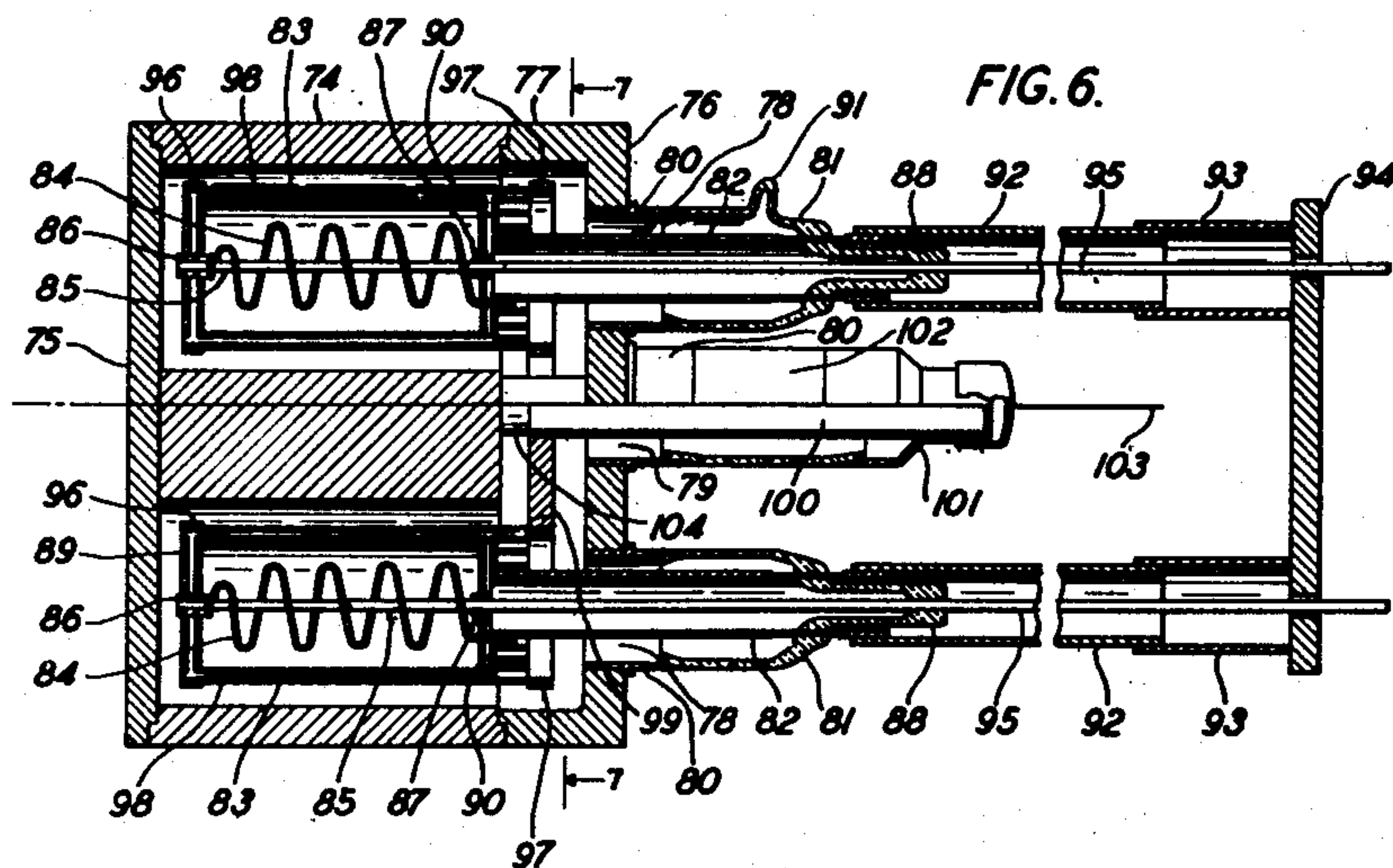
BY:
Walter C. Kiesel
ATTORNEY

July 8, 1947.

C. E. FAY
HIGH POWER ELECTRONIC DISCHARGE DEVICE FOR GENERATING
ULTRA-HIGH FREQUENCY RADIATIONS
Filed Dec. 31, 1942

2,423,443

3 Sheets-Sheet 2



INVENTOR
C. E. FAY

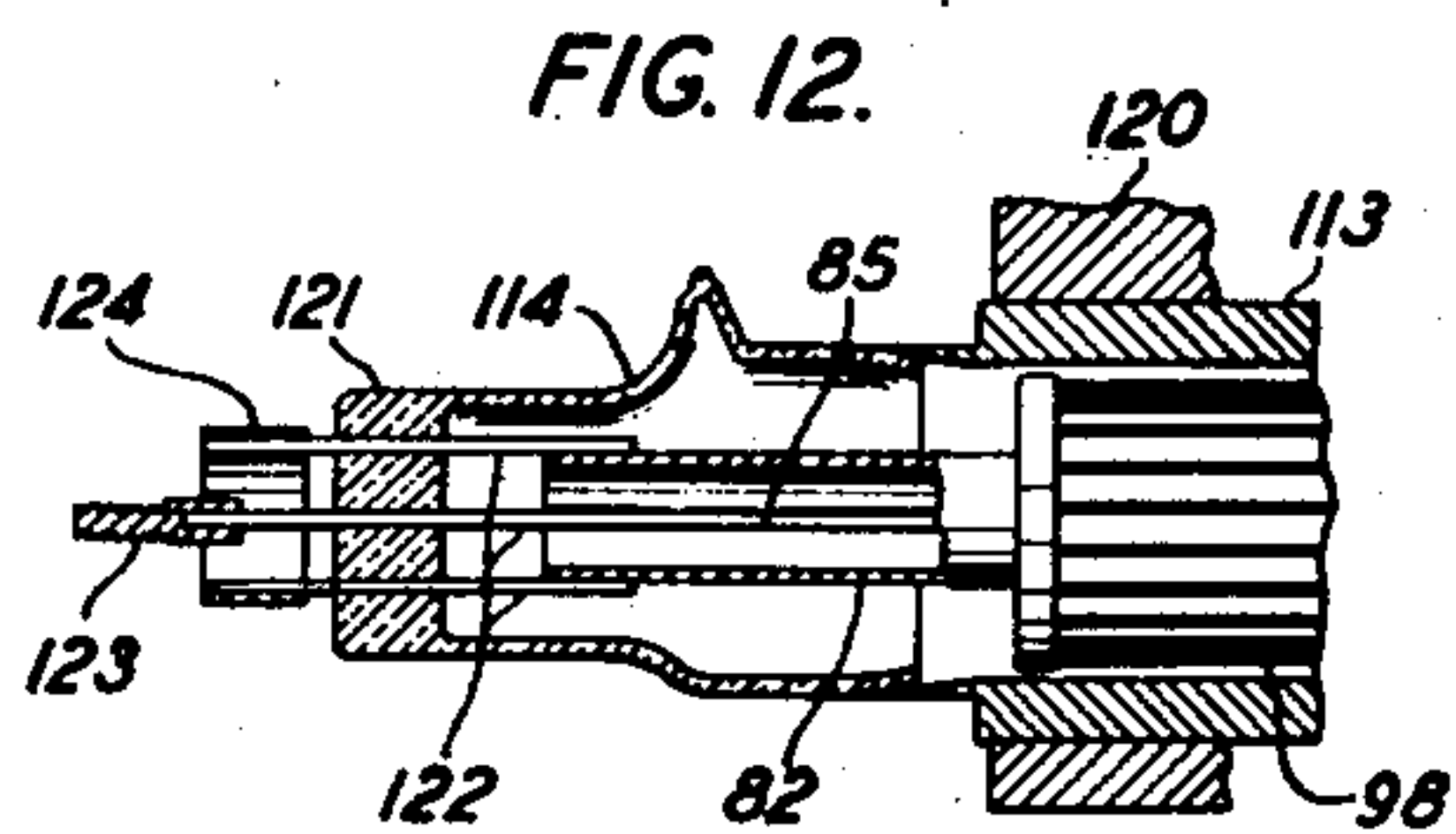
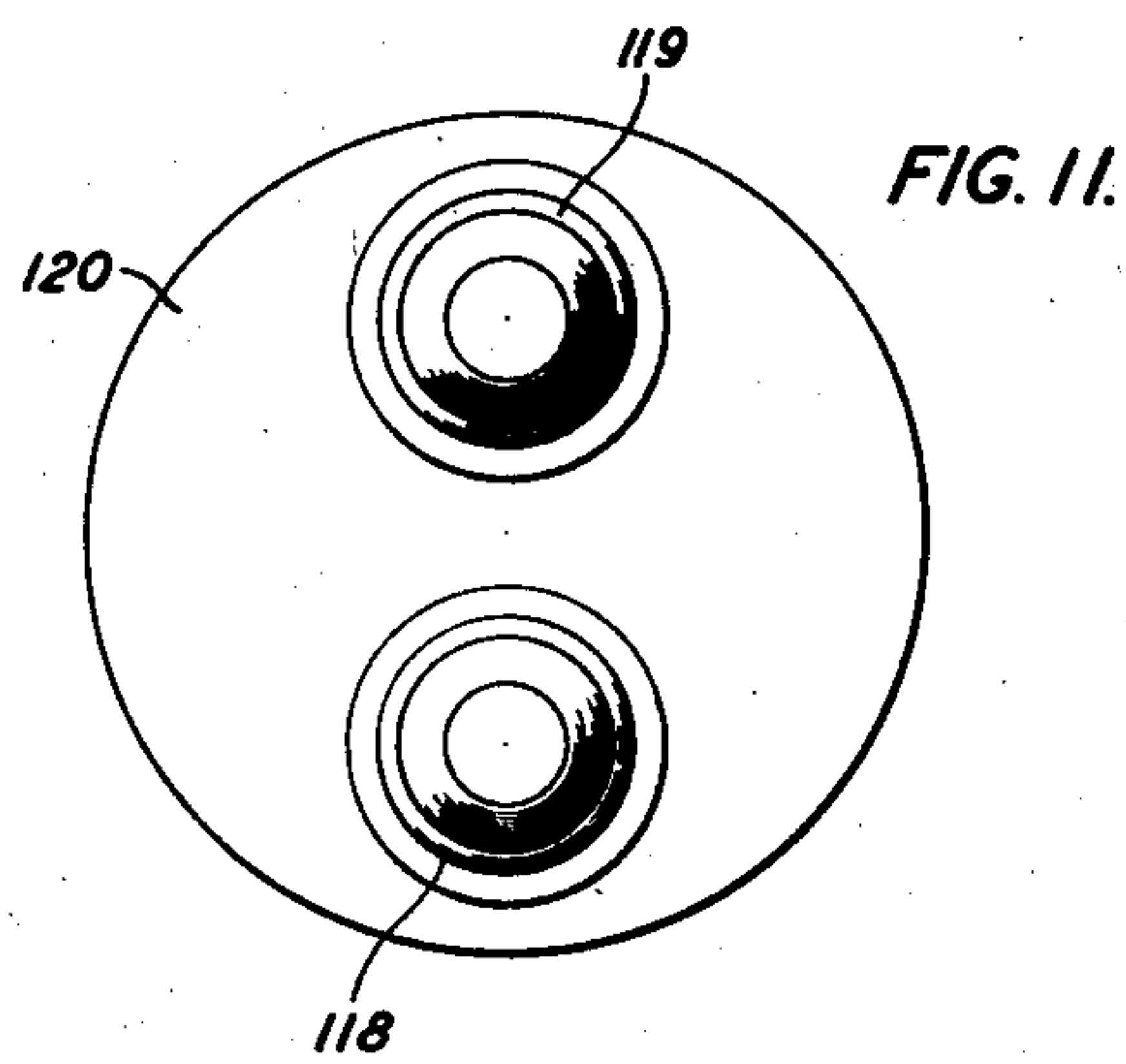
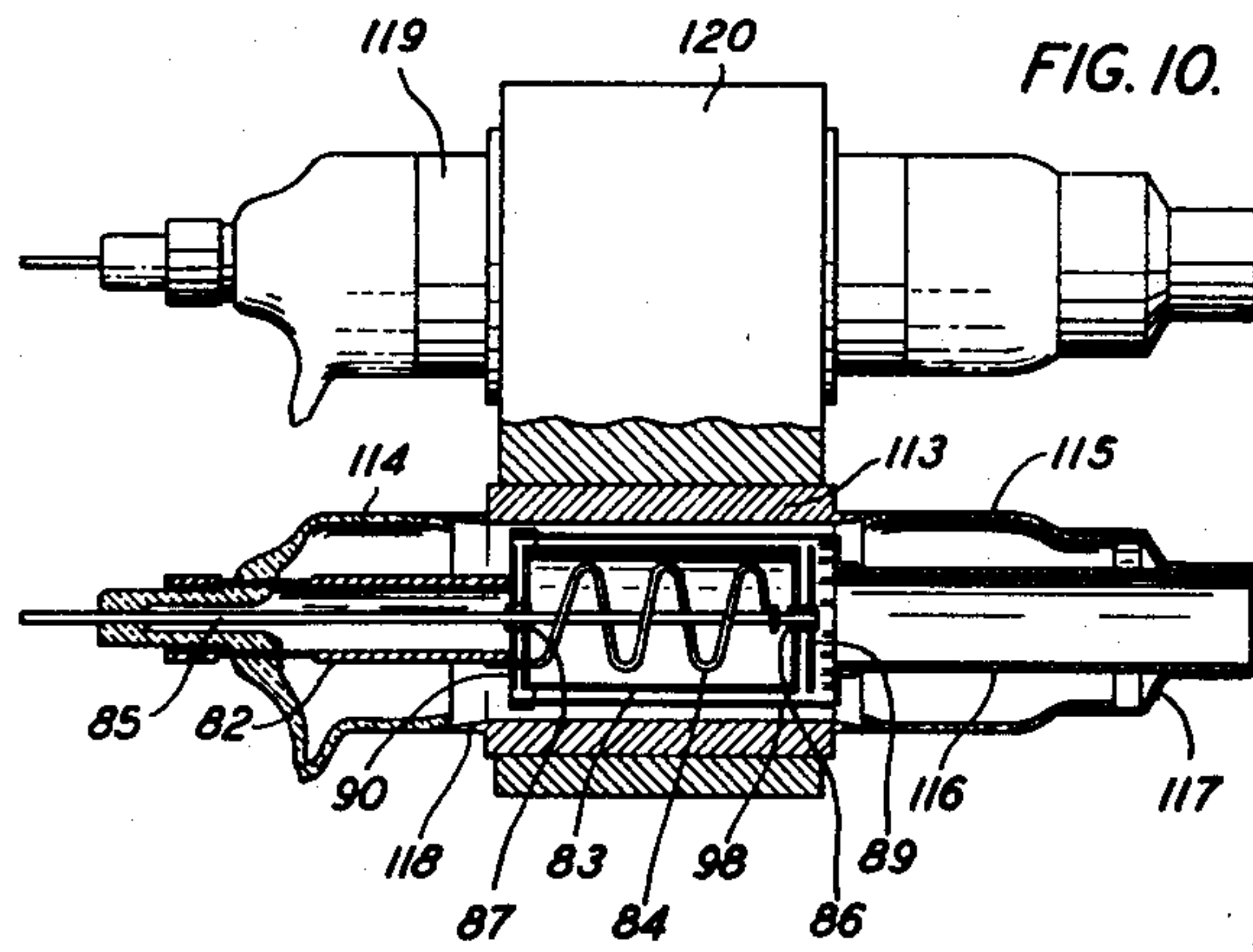
BY:
Walter C. Kiesel
ATTORNEY

July 8, 1947.

C. E. FAY
HIGH POWER ELECTRONIC DISCHARGE DEVICE FOR GENERATING
ULTRA-HIGH FREQUENCY RADIATIONS
Filed Dec. 31, 1942

2,423,443

3 Sheets-Sheet 3



INVENTOR
C. E. FAY

BY:

Walter C. Kiesel
ATTORNEY

UNITED STATES PATENT OFFICE

2,423,443

HIGH POWER ELECTRONIC DISCHARGE
DEVICE FOR GENERATING ULTRA HIGH
FREQUENCY RADIATIONSClifford E. Fay, Chatham, N. J., assignor to Bell
Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application December 31, 1942, Serial No. 470,795

17 Claims. (Cl. 250—27.5)

1

This invention relates to high power electronic discharge devices for generating ultra-high frequency radiations and more particularly to such devices employed in generating ultra-high frequency energy radiations.

The primary object of the invention is to increase the power output of an electronic generator in a definite frequency range.

Another object of the invention is to overcome mechanical limitations in the construction of the device so that the only limiting factor affecting the efficiency is the electron transit time.

A further object of the invention is to produce a self-shielding assembly to prevent extraneous disturbances affecting the internal impedance of the device and also to prevent radiation of radio frequency energy from the enclosure except through the output circuit.

A still further object of the invention is to attenuate the over-all dimensions of the device for convenience of utilization while proportioning the dynamic and electrostatic characteristics of the generator.

Another object is to stabilize the inductive coupling between cooperating units of the device in a symmetrical assembly having constant characteristics and capable of yielding a high power output with a minimum loss in efficiency.

A further object of the invention is to facilitate adjustment of the frequency characteristics of the device to compensate for differences of internal relation of the cooperating electrodes of the device.

These objects and advantages are achieved in accordance with this invention by various constructions of electronic oscillation generator devices comprising a pair of cooperating units or multiples thereof adapted for reciprocal or push-pull operation to produce a power output of high efficiency and ultra-high frequency in a definite short wave range for operation in microwave energy transmission systems.

The device may be embodied in a duplex construction of units having a metallic casing, each end of which forms an external anode element which may be cooled to dissipate heat energy and the casing forming a hermetically sealed container enclosing and shielding the complete oscillating components for generating the power to be utilized in the operation of the device. A dual control electrode assembly is mounted within the casing in symmetrical relation to the anode elements of the device and cooperates therewith to form capacitive and inductive resonance chambers or cavities for coupling these electrodes in

2

an oscillatory circuit. A dual cathode assembly is mounted within the grid assembly and is coaxially related thereto along the whole length of the device to produce the high electron source for each unit and introduce distributed capacity and inductance components in the communicating path to the control electrodes. This construction facilitates the introduction of the supply conductors to the cathode and control assemblies at a medial plane of the device where the high frequency voltages are negligible so that energy strains do not occur in the seals of the conductors.

Furthermore, the coaxial coupling members of the individual dual electrodes are utilized to control and regulate the frequency range of the device and to proportion the values of the lumped impedances in the oscillation generator. These members have definite ratios of diameter to the electrode surfaces so that the device may be considerably attenuated in length for definite microwave band operation. A feature of this construction is the self-shielding effect the substantially completely metallic casing offers to the electromagnetic fields within the casing so that external disturbing fields are isolated from the discharge paths within the casing, and the fields within the casing are isolated from other apparatus external to the device.

Another feature of this construction is the uniformity of the coaxial coupling members of the dual electrodes which offer symmetrical paths for the ultra-high frequency current transversing the space within the device so that the reciprocal operation of the duplex units results in high efficiency in power output and more stable functioning of the oscillatory operation of the device.

The construction may also be embodied in a multiplex assembly having four cathodes disposed in hollow cavities of an anode mass and the cathodes being surrounded by cooperating control elements which are coupled together within the anode and joined to a conductor insulatingly mounted on one end of the anode mass. The cathodes also extend individually from the same end of the anode and may be utilized for coupling a tuned loop thereto for the output load circuit.

The feature of this assembly is the complete absence of solid dielectric material between the various electrodes of the multiplex unit within the anode casing so that there are no radio frequency dielectric losses within the device. This construction produces a high quality oscillation generator of high power output at ultra-high frequencies. Some of the advantages of the mul-

tiplex unit may be gained in a duplex unit embodying two self-contained structures mounted in an anode mass with the dual cathodes at one end and the dual control electrodes at the other end.

These and other features and capabilities of the devices of this invention will be more clearly understood from the following detailed description when considered with the accompanying drawings.

Fig. 1 illustrates a duplex oscillation generator made in accordance with this invention, and shown partly in section and partly broken away to clearly disclose the detail assembly of the device;

Fig. 2 is a cross section view taken across the central portion of the device and illustrates the mounting thereof and the various connections for the internal electrodes;

Fig. 3 is a partial view in perspective on an enlarged scale of the assembly of the cathode and control electrode in either end of the device;

Fig. 4 is a schematic view of the circuit components constituting the structural elements and resonance cavities of the device of Fig. 1;

Fig. 5 shows a potential distribution diagram of the alternating potentials of the elements of a device of the type of Fig. 1;

Fig. 6 shows a modification of the invention substantially in cross section in which the internal elements are multiplied and supported from one end of the device;

Fig. 7 is a plan view in cross section of the device of Fig. 6 taken on the line 7—7;

Fig. 8 shows a representative schematic for the utilization of the device of Fig. 6 as an oscillation generator;

Fig. 9 illustrates in perspective the phases of the current flow in the structural assembly of the device of Fig. 6;

Fig. 10 shows another modification of the invention in which twin units are combined in a structure partly broken away and partly shown in section to illustrate the internal assembly;

Fig. 11 is a plan view of Fig. 10; and

Fig. 12 shows a view in cross section of a further modification in the terminal construction of the units embodied in the device of Fig. 10.

Referring to the drawings and particularly to Figs. 1, 2 and 3, the embodiment of the oscillation generator of this invention as shown therein comprises a completely enclosed metallic casing, which forms a highly evacuated container or vessel for the dual or duplex units which constitute the reciprocal oscillation generator elements for producing ultra-high frequency energy in microwave band transmission systems. The casing is formed of an intermediate cylindrical shell 20 which is hermetically joined to a pair of terminating solid metallic masses 21 and 22, preferably of copper, having a central passageway therethrough of considerably less diameter than the diameter of the intermediate shell 20. The masses 21 and 22 constitute external anode portions of the device and may be provided with circumferential radial fins 23 for readily dissipating the heat energy generated in the copper mass of the anodes during the operation of the device. The cooling fins may be replaced by any other type of cooling instrumentality, such as a water circulating jacket or a coil of pipe surrounding the anode mass, the fins being shown as one example of cooling means for dissipating the heat energy by air conduction. The casing may be mounted in a horizontal position by a plurality

of footing studs 24 which rest on a suitable base 25, as shown in Fig. 2, so that the device may be associated with other cooperating elements to constitute the transmission system employing the energy generated in the device.

The shell and anode portions enclose dual or duplex electrode assemblies mounted in cooperating relation to the shell and anode portions so that the device functions as a push-pull triode oscillation generator in which the current flows reciprocally in opposite phases between the two triodes to generate high power at ultra-high frequencies in the range from zero to 1500 megacycles, with a power output of 1 to 5 kilowatts depending on the dimensions and constants of the electrodes and resonance cavities of the device. In order to proportion the capacitances between the electrodes in each triode and also to reduce the transit time of the electron flow to a minimum the cooperating electrodes within each anode portion are mounted coaxially and relatively close to the internal surface of the mass defined by the central opening therein.

The cooperating electrode assemblies are oppositely disposed box-like cylindrical cathodes 26 and 27 and oppositely disposed cylindrical open-work control electrodes or grids 28 and 29 coaxially positioned in the openings of the anode portions 21 and 22, respectively. The cathodes have a large cylindrical surface uniformly spaced in close relation to the internal surfaces of the anode portions and this surface is coated with an electron emissive material 30, such as barium and strontium oxides, to supply a copious emission of electrons across the short gap to the anode in order to convey the large current necessary to generate the high power to be delivered by the device. The duplex cathodes are electrically connected together in opposed relation by a coupling sleeve or coaxial conducting member 31 and the duplex grids are electrically connected together by a smaller sleeve 32 of larger diameter, both sleeves being in concentric relation to the intermediate shell portion 20 of the device. A central support rod or conductor 33 extends through both cathodes and the sleeve 31, the rod being insulated from the cathode enclosures by insulating bushings 34. Each cathode is heated to emission temperature by an internal heater element 35, of tungsten, which may be in the form of a large diameter helix surrounding the rod 33 and being attached at one end to the rod and at the other end to the terminating end of the sleeve 31. The cathode is also provided with end disc shields 36 and 37 to serve as heat deflectors for confining the heat energy of the cathode to the cylindrical surface opposed to the anode surface. Each control grid is formed of an end disc 38 having a flanged periphery and a central opening 39 which forms a partial electrostatic shield between the cathode and the anode. A plurality of parallel wires 40 extend between the grid disc 38 and the coupling sleeve 32 and are interposed between the active cathode surface and the internal surface of the anode portion.

The cathode coupling sleeve 31 is coaxially mounted within and with respect to the grid coupling sleeve 32 by a plurality of radially disposed insulating brackets or arms 41 which are attached thereto at the medial plane of the sleeves. In a similar manner the coupling sleeve 32 is coaxially mounted with respect to the intermediate shell 20 by a plurality of radial insulating arms 42 which radiate in staggered relation

5

to the arms 41 and are attached to integral lugs 43 mounted on the inner surface of the shell 20. These arms rigidly support the coaxial system of electrodes in the casing and reduce to a minimum the dielectric material contained within the device so that the high frequency loss due to insulating material being within the high frequency fields is materially reduced. Furthermore, the insulating support arms are located at the nodal point between the two triodes where the radio frequency potential differences are small, so that no stresses are apt to occur in the insulating members as a result thereof. For this same reason the conductors for the various electrodes are introduced into the casing in the same medial plane as the insulators and, due to the fact that the insulators are staggered, the conductors are readily attached to the respective electrodes through the shortest possible paths. For this purpose a plurality of metallic nipples 44 are threaded into the periphery of the shell 20 at a medial position and are brazed thereto with hard solder. Each nipple is provided with an exterior knife edge lip 45 which is hermetically sealed to one end of a glass tubulation 46. A conductor 47 extends radially through one of the glass tubulations 46 and is sealed thereto at the outer end. An extension 48 of the conductor projects through the sleeves 32 and 31, respectively, and is connected to the central rod 33. The conductor 47 may also be provided with a flexible link 49, in the form of a loop, to compensate for expansion and contraction of the conductor. Another conductor 50 extends through another seal, 90 degrees away from the conductor 47 and is connected to the grid sleeve 32, and a conductor 51 extends through the intermediate seal and is connected to an extension 52 which projects through the sleeve 32 and is connected to the cathode sleeve 31, the conductors 47 and 51 supplying current for the heater elements 35 and their respective cathodes, and the conductor 50 supplying current to the grids in the assembly. A glass seal 53 is provided for the remaining nipple, whereby the device is efficiently evacuated of residual and occluded gases so that a high vacuum may be maintained within the casing. A large diameter nipple 54 is also brazed to the shell 20 in opposed relation to the conductor 50 of the grid and a reentrant glass seal 55 interconnects the nipple to a copper thimble terminal 56 which supports a solid conductor 57 connected to a pick-up loop 58 extending into the area between the shell 20 and the sleeve 32 which is suitably connected to the shell, to form a portion of the coaxial output load circuit of the device.

As shown in Fig. 1, the device may be provided at either end with a frequency adjusting terminating element 59 and 60 to regulate the capacitive coupling within the active electrode areas between the control electrodes and the anodes. The terminating element comprises a flanged cap 61 hermetically soldered over the opening in the anode mass and is provided internally with a flexible bellows type collar 62, hermetically jointed to the cap and to a flat metallic disc 63 having a diameter slightly less than the diameter of the opening in the anode and being mounted adjacent the disc shield 38 of the grid. The disc 63 is variably movable in reciprocal relation by a thumb screw 64, to change the capacitive coupling between the anode and the grid in the anode cavity and thereby accurately tune the anode grid circuit to the desired frequency.

6

The construction of the duplex device, in accordance with this invention, as hereinbefore described, fulfills many essential requirements for attaining a high power output of high quality and high efficiency in a microwave band transmission system. Furthermore, this construction materially increases the utility of the device by the proper proportioning of the elemental components of the device, since the efficiency and the amount of the power output is determined by the relation between the electrodes, the resonance cavities between the electrodes and the reciprocal current paths between opposed assemblies in the device.

In order to derive a large power output, it is necessary to maintain a large source of electron flow in the device and to reduce the transit time of the electron travel to a minimum it is necessary to keep the interelectrode spacing as small as possible. This latter factor also determines the interelectrode capacities between the cathode and grid, the grid and anode and the cathode and anode in each triode. Since these capacities are fixed by the configuration of the electrodes and their space relation, very little change can be made, depending on the definite frequency of operation and the power output desired, in these components in the device. However, in operating push-pull oscillation generators at a desired frequency and particularly at a frequency of microwave length, it is essential to correlate the inductive components of the system with the internal capacitance of the device in order to attain a high efficiency in power output.

Therefore, in the device of this invention, these difficulties and many other mechanical difficulties in the transmission of the radio frequencies between the opposed units are overcome by a definite relation of the current paths between the units in order to correlate the complete oscillating circuit within the device. As a primary advantage, the metallic casing provides substantially distortionless fields within the current paths in the device, due to the complete shielding effect the casing offers to spurious disturbing fields external to the device. The low radio frequency loss in the discharge paths due to the minimum dielectric material enclosed within the casing presents another advantage of this construction. A further attribute of the device of this invention is the proportioning of the resonance cavities coupling the duplex units to resonate at a definite frequency with the internal capacities of the electrodes and to accomplish this effect by attenuating the over-all length of the device while maintaining the proper wave-length values to coincide with microwave band operation.

Assuming, for example, that a duplex device of the triode type has electrodes of certain diameters to operate in an oscillating circuit at a frequency of 200 megacycles. If the coupling sleeves 31, 32 and 20 connecting the opposed pairs of respective electrodes are the same diameters as the electrodes, the length of the device would be 75 centimeters or 30 inches to provide resonance cavities between the triodes of one-half wave-length. In accordance with this invention, the length of the device L is shortened to 18 inches at the indicated frequency and this length may be materially decreased for higher frequencies, for example, 8 inches for 400 megacycles or $6\frac{1}{2}$ inches for 500 megacycles.

This is produced by increasing the diameter of the shell 20 considerably beyond the diameter of the internal anode surfaces and decreasing the

diameter of the coupling sleeve 31 with respect to the diameter of the cathodes, whereby the inductive components of the cavities between the shell 20 and the grid sleeve 32 and the cathode sleeve 31 and the grid sleeve 32 are properly proportioned and correlated with the capacitive components of the electrodes at the respective frequencies to provide balanced oscillatory paths in which the opposed phases of current can be efficiently absorbed in the output path between the shell and grid sleeve by a transmission loop 58 and conveyed to the output circuit of the device. With a diameter D of four inches for the shell 20, one-half the length L from one end to the center of the shell 20 and sleeves 31 and 32 will be 7.15 inches for 200 megacycles, 2.07 inches for 400 megacycles and 1.33 inches for 500 megacycles. It is easily seen that the proposed combination effects a material attenuation in the length of the device when compared to the assumed example without sacrificing the efficiency and the maintenance of the definite frequency band of operation.

The addition of extra loading capacitance between grid and anode, and between cathode and grid will allow a further shortening of the length L. This may be accomplished by mounting a disc 32a on sleeve 32 adjacent to the lower surface of anode mass 21 which will have the effect of adding to the interelectrode capacitance between grid and anode, and also a sleeve 31a mounted on the inner heat shield 37 of the cathode, to add capacitance to the cathode-grid interelectrode capacitance. With these additions in the approximate proportions indicated, one-half the length L is further reduced at 200 megacycles to 4.13 inches.

The efficiency of the power output is increased by the correlation of the magnitude of the electron emission, minimum transit time of electron flow between the cathode and anode, the capacitive coupling between the cathode and grid, cathode and anode and grid and anode, and the proportioning of the resonance cavities or chambers interconnecting the similar electrodes in opposite phase relation, the proportioning of the chambers being such as to provide the proper reactances between the active electrodes and the whole internal circuit involving these components being designed to produce a high efficiency in a definite frequency range depending on the overall dimensions of the device.

This correlation may be made evident by reference to the diagrammatic equivalent of the device of Fig. 1 as shown in Fig. 4. The anode 21 and cathode 26 have a capacitive component C5 which corresponds to the cylindrical spacing between these electrodes. Likewise a capacity C6 is represented between the cathode 26 and the grid 23 and a bridging capacitance 67 couples the grid and anode. This capacity is variable, due to the adjustable plate 63, to return the circuit depending on variations between the grid and anode surfaces. Similarly, the capacities 68, 69 and 70 represent the distributed electrostatic couplings between the anode 22, cathode 27, and grid 29, respectively, at the opposite end of the device which have exact values corresponding to the capacities associated with the circuit involving the anode 21. The cathodes 26 and 27 are coupled together by an inductance 71 which corresponds to sleeve 31 in the chamber of sleeve 32 while the grids 28 and 29 are coupled together by an inductance 72, corresponding to sleeve 32 in the chamber of shell 20, and the anodes 21

and 22 are coupled by an inductance 73 which represents the chamber between sleeve 32 and shell 20. These inductances resonate with the coupled and loading capacities between the electrodes at the desired frequency for which the device is designed and by the absence of disturbing external fields due to the shielding effect of the metallic casing of the device, the wholly enclosed oscillatory circuit produces a high quality power output of the order of 1 to 5 kilowatts with high efficiency.

The flow of current in the duplex device, due to the particular construction and the proportioning of the components, produces uniform energy oscillations since the potentials applied to the unit composed of cathode 27, grid 29 and anode 22 are the same as applied to the unit involving cathode 26, grid 28 and anode 21 except that the phase relation is opposite. This uniformity can be realized from the potential distribution plot, as shown in Fig. 5, in which the P₁, P₂ curve represents the alternating potential at the peak of a cycle between anodes 21 and 22, the curve G₁ and G₂ represents the potential distribution between grids 28 and 29 and the curve F₁ and F₂, shown in dotted line, represents the potential distribution between cathodes 26 and 27, the cathode potential being determined by the anode-cathode and grid-cathode capacities in each unit and the potentials on these electrodes. If the capacities are in inverse ratio to the potentials, the cathode potential would always be zero. If not, the cathodes are free to assume the potential dictated by these conditions if the two cathodes are effectively connected by a coaxial cavity of one-half wave-length. If the cathodes are connected by a cavity differing from an effective half wave-length, the cathode potentials may be made to have the values desired by suitably proportioning this cavity. The potential distribution of the radio frequency energy illustrates the effective zero node of the potential at the medial point of the system where the supporting insulating arms and the conductors are situated so that energy loss and strain in the insulators and seals, respectively, are a minimum.

Referring to Figs. 6 and 7, a device of similar capacity but different construction than that heretofore described is shown in which the cathode and grid structures are subdivided into multiplex units and enclosed in a substantially solid mass which constitutes the external anode of the device. This structure comprises a cylindrical copper block 74 having four equally spaced openings drilled therethrough to form the anode cavities or chambers for the individual units of cooperating electrodes mounted therein. A cover plate 75 is brazed to one end of the block and a cover plate 76 having a cylindrical flange portion 77 is brazed to the other end of the block to substantially close the resonating cavities within the block. The cover plate 76 is provided with apertures 78 corresponding to and aligned with the openings in the block and is also provided with a central aperture 79 coaxial with the axis of the block. The solid external anode 74 may be cooled in any suitable manner such as being surrounded with a fin assembly, not shown, or a water-cooling jacket, not shown, to efficiently dissipate the heat energy generated in the operation of the device. A copper collar 80 is soldered in each aperture 78 of the cover member, the collar being provided with the usual knife edge termination exterior to the cover member in order to seal a glass tubulation 81 thereto

which is contracted at the opposite end and sealed to the exterior surface of a tubular conductor 82 extending into the anode block and being coaxially arranged with respect to the axis of an opening in the block.

The tubular conductor 82 supports a cylindrical box-like cathode 83, which is closed at opposite ends and contains a helical heater element 84, which is supported by a central rod 85 secured to the cathode assembly at one end by an insulating bushing 86 and at the other end is insulated from the cathode by a bushing 87, the heater element being attached to the tubular conductor 82 at the termination of the hollow cathode. The rod 85 extends through the tubular conductor 82 and is sealed in position by a glass stem 88 which is joined to the rod and the interior of the tubular conductor 82. The cathode is also provided with end heat deflector shields 89 and 90 and the cylindrical surface is coated with emissive electron material, such as barium and strontium oxides, to project the electrons in a radial direction to the surrounding anode surface adjacent thereto, the cathode being heated to emission temperature by the enclosed heating element 84. The heating current is supplied through the central support rod 85 then through the heater and returns through the tubular conductor 82, the cathode being held at the potential of one side of the heating circuit through its connection to the tubular conductor 82. Each of the cathodes mounted in an anode cavity is of similar construction and together constitute a source of large magnitude in supplying electron flow to the multiple anode surfaces. One of the tubulations 81 may be provided with a sealing tip 91 whereby the interior of the device may be highly evacuated and occluded gases removed therefrom. The four cathode assemblies therefore represent four parallel coaxial structures which may be connected in parallel and tuned to any desired frequency by a Lecher transmission line in which coaxial adjustable pipes or tubes 92 and 93 are placed in contact with the tubular conductors 82 of the cathodes and are bridged by a shorting bar 94 having openings to permit an extension 95 of the central conductors 85 to project therefrom for connection to the heating circuit.

The control electrode or grid is mounted in coaxial relation to each cathode and the anode cavity and comprises a pair of end rings or collars 96 and 97 between which are mounted a plurality of parallel spaced wires 98 to form a cylindrical cage electrode. The grids are coaxially mounted with respect to the cathodes and anode surfaces and are combined in a unitary structure by an H-type yoke support 99 in which the collars 97 of the grids are secured in circular openings on opposite ends of the arms of the yoke, the circular openings forming passageways for the tubular conductors 82 of the cathode assemblies. The yoke support and the grids attached thereto are connected to a central conductor 100 which is seated in an external thimble 101, sealed to a glass tubulation 102 extending between the thimble and the knife edge collar in aperture 79. A conductor 103 may be connected externally to the thimble 101 to maintain the grid system at the proper bias potential. Due to the expanse of the cover member 76 of the anode casing and the number of large apertures formed therein for the lead-in conductors for the multiplex electrodes, the planary surface of the cover member may be distorted by buckling because of

the differences in pressure within and external to the device. This may be avoided by maintaining the surface of the cover member in uniform relation to the parallel surface of the anode block by a pair of spacing studs or pillars 104 which may project either from the cover member 76 or the anode block 74 and extend on opposite sides of the center of the yoke support 99 to engage the opposite surface of the anode or cover respectively, depending on which element the studs extend therefrom, to constitute permanent spacing pillars thereby maintaining uniform spaced relation of the cover member with respect to the anode block.

An advantage of this construction is the total absence of dielectric material within the evacuated portion of the device between the various units where the radio frequency energy can be dissipated. Furthermore, the form of yoke support for the control electrodes mounted in the common cavity of the anode between the units provides an inductance coupling member which is represented in Fig. 8 by the numeral 105, the inductance having a value which is related to the interelectrode capacities between the cathodes, grids and anodes as represented by the opposite phases of the devices 106 and 107 which are mutually tuned by the Lecher inductance 108. The nodal points of these inductances are coupled by a high resistance grid leak 109. The power input is supplied to the circuit by conductor 110, the anode being at ground potential as indicated by 111. The flow of the opposite phases of the oscillatory current in the device is represented in Fig. 9 in which the control electrodes 98 connected at opposite ends to one arm of the yoke support 99 and the cathodes associated therewith in association with the cooperating anode surfaces 74 provide the path for one phase of the current while the opposite pair of electrodes provide a path for the opposite phase of the current, as indicated by the direction of the arrows in this figure. The radio frequency power output is derived by the coupled tuned Lecher line 112 which is connected to any suitable load circuit.

The low loss construction of the device of Fig. 6 may be utilized in a double ended construction, as shown in Fig. 10, in which a self-contained triode unit comprising a cylindrical anode portion 113 is provided with glass portions 114 and 115 at opposite ends and a cathode and coaxial conductor assembly, as described in connection with Fig. 6, is supported from the glass portion 114 while an individual grid 98, supported by a tubular conductor 116 mounted in a thimble terminal 117 is carried by the insulating portion 115. Two of such units 118 and 119 may be mounted in parallel relation in a solid copper block 120 which serves as the external anode of the dual assembly, the block being cooled by any suitable means to dissipate the heat energy. This construction provides a symmetrical assembly which may be utilized in a circuit similar to Fig. 8 to generate ultra-high frequencies with a power output commensurate with the dimensional components of the device. As shown in Fig. 12, the glass portion 114 of the unit may be modified to provide a flat press 121 to form a seal for three conductors 122 for the cathode circuit in which the internal tubular conductor 82 is connected to the outer lead-in conductors 122 while the center wire forms a continuation of the heater support rod 85 of the cathode. The coaxial termination of the cathode circuit may be resumed after leaving the

11

seal 121 of the glass portion by connecting a terminal 123 to the center rod or wire and a sleeve 124 to the outer wires. The purpose of this construction is to simplify the sealing arrangement of the cathode conductors yet provide the coaxial conductors for connection to the Lecher line.

While the invention has been disclosed in various embodiments directed to specific details of construction of the assemblies, it is, of course, understood that various modifications may be made in the cooperation of the units and the proportioning of the various components to produce structures of similar characteristics but differing from the detail assembly as shown, and therefore, it is intended that the invention is to be determined by the scope of the appended claims.

What is claimed is:

1. An electron discharge device comprising an evacuated, unitary metallic container having a plurality of anode surfaces, a plurality of cylindrical control electrodes insulatingly supported within said container and uniformly spaced with respect to said anode surfaces, a cylindrical cathode insulatingly mounted within each control electrode, cylindrical metallic means connecting said control electrodes together as a unit, a coaxial coupling member within said means joining the cathodes together as a unit, a conductor insulatingly sealed to said container and centrally connected to said means for said control electrodes, and conductors connected to the cathodes, centrally sealed through said container with respect to the length and insulated therefrom.

2. An electron discharge device comprising an evacuated, unitary metallic container having a plurality of anode surfaces, a pair of cylindrical control electrodes insulatingly supported within said container and uniformly spaced with respect to said anode surfaces, a cylindrical cathode insulatingly mounted within each control electrode, a symmetrical continuous coupling member connecting the control electrodes together as a unit, a smaller diameter coupling member connecting the cathodes in series relation as a unit, a conductor insulatingly sealed through said container and centrally connected to said coupling member for the control electrodes, and conductors connected to the cathodes sealed through said container and insulated therefrom.

3. An electron discharge device comprising an evacuated, unitary metallic container having a plurality of cylindrical cavities and anode surfaces, a cylindrical control electrode insulatingly supported within each cavity and uniformly spaced with respect to each anode surface, a cylindrical hollow cathode insulatingly mounted within each control electrode, a symmetrical coupling member coaxially mounted with respect to said container outside the area of said cavities and connecting adjacent ends of the control electrodes together as a unit, an inner cylindrical coupling member joining the cathodes, a conductor insulatingly sealed to said container and centrally connected to said coupling member for the control electrodes, and conductors connected to the cathodes sealed through said container and insulated therefrom, the ratios of diameters of said anode surfaces, each control electrode and cathode and said coupling members being so related that the lumped impedances are proportioned in the cavities therebetween whereby the length of the device is materially reduced for a prescribed band of microwave frequencies.

12

4. An electron discharge device comprising an evacuated, unitary metallic container having a plurality of cavities and anode surfaces, a cylindrical control electrode insulatingly supported within each cavity and uniformly spaced with respect to each anode surface, a cylindrical hollow cathode insulatingly mounted within each control electrode, inner and outer coaxial interconnecting members within said container joining the control electrodes and cathodes respectively as coaxial units, the inner member being of smaller diameter than the cathodes, a conductor insulatingly sealed through said container and centrally connected to the outer interconnecting member perpendicular to the surface of said member to supply a potential to said control electrodes, and conductors connected to the cathodes sealed through said container and insulated therefrom.

5. An electron discharge device comprising a pair of oppositely disposed metallic anode portions having large central cavities, a pair of oppositely disposed cylindrical control electrodes coaxially extending into the cavities of said anode portions, a pair of oppositely disposed cylindrical cathodes extending within said control electrodes, coaxial cylindrical metallic coupling members secured to said anode portions, control electrodes and cathodes, respectively, interconnecting each pair in conductive relation, and insulating means spacing the inner and intermediate coupling members from the outer member at the medial plane of said device.

6. An electron discharge device according to claim 5 in which the coupling member interconnecting said anodes is of greater diameter than the diameter of the cavities, and the diameter of the coupling member interconnecting said cathodes is of smaller diameter than said cathodes.

7. An electron discharge device comprising a pair of oppositely disposed anode portions having large central cavities, a pair of oppositely disposed cylindrical control electrodes coaxially extending into the cavities of said anode portions, a pair of oppositely disposed cylindrical cathodes extending within said control electrodes, the annular spaces between adjacent electrodes on each end forming distributed capacitances between the respective electrodes, coaxial coupling sleeves connected between respective pairs of similar electrodes, insulating arms extending radially between said sleeves in a medial plane of said device, and loading capacitances interposed between the electrodes and said sleeves.

8. An electron discharge device comprising a pair of oppositely disposed anode portions, a pair of oppositely disposed control electrodes extending within said anode portions, a pair of oppositely disposed cathodes within said control electrodes, the space between adjacent electrodes on each end forming distributed capacitance between the respective electrodes, coaxial coupling sleeves interconnecting pairs of similar electrodes, insulating spacer members connecting adjacent sleeves at a medial portion of said device, an annular member extending outwardly from the sleeve connecting said control electrodes and in spaced relation to a surface of said anode, and a tubular member extending from the cathode and mounted coaxially in spaced relation to said sleeve connecting said control electrodes.

9. An electron discharge device comprising a pair of oppositely disposed metallic anode portions having central cavities of large area, a pair of oppositely disposed cylindrical control elec-

13

trodes coaxially extending into said cavities of said anode portions, a pair of oppositely disposed cylindrical cathodes extending within said control electrodes, coaxial cylindrical metallic coupling members secured to said anodes, control electrodes and cathodes, respectively, interconnecting each pair in conductive relation, and radial insulating arms spacing said coupling members in uniform relation.

10. An electron discharge device comprising a pair of oppositely disposed metallic anode portions having large central cavities, a pair of oppositely disposed cylindrical control electrodes coaxially extending into said cavities, a pair of oppositely disposed cylindrical cathodes extending within said control electrodes, coaxial cylindrical metallic coupling members secured to said anodes, control electrodes and cathodes, respectively, interconnecting each pair in conductive relation, insulating spacing arms connecting adjacent coupling members at a medial point in said device, and a plurality of conductors insulatively projecting through said coupling member interconnecting said anodes at a medial plane, said conductors being joined to separate coupling members for applying potentials to said cathodes, control electrodes and anodes.

11. An electron discharge device comprising a pair of oppositely disposed metallic anode portions having large central cavities, a pair of oppositely disposed cylindrical control electrodes coaxially extending into said cavities, a pair of oppositely disposed cylindrical cathodes extending within said control electrodes, coaxial cylindrical metallic coupling members secured to said anodes, control electrodes and cathodes, respectively, interconnecting each pair in conductive relation, radial insulating arms spacing said coupling members in uniform relation, a plurality of conductors insulatively projecting through said coupling member interconnecting said anodes, said conductors being joined to separate coupling members of said cathodes, control electrodes and anodes, and frequency adjusting means adjacent the outer end of either of said anode portions for cooperation with said control electrodes within said cavities.

12. A discharge device according to claim 8 in which a metallic cap extends across one end of a cavity in one anode portion, a flat plate within said cavity in parallel relation to a surface of a control electrode, a resilient metallic sleeve member hermetically sealed to said plate and cap, and an adjustable member extending through said cap and sleeve and connected to said plate to vary the capacitive space relation between said anode portion and said control electrode.

13. An electron discharge device comprising a double-ended metallic vessel having opposite end portions forming external anodes of the device, a pair of concentric cylindrical metallic members within said vessel and mounted at an intermediate portion thereof, a cylindrical open-work electrode supported on each end of one of said members and extending within a cooperating anode, a cylindrical cathode closed at opposite ends supported on each end of the other of said members and disposed within its respective open-work electrode, a central rod extending through said cathodes, individual heater elements within said cathodes connected to said cathodes and rod, and a plurality of conductors insulatively extending through said vessel at a medial plane, said conductors being connected to said rod, metallic members and vessel, respectively.

14

14. A push-pull oscillation generator comprising a metallic casing having hollow anode portions at opposite ends thereof and an intermediate portion joined to said anode portions having a larger diameter than the internal diameters of said anode portions, a pair of hollow cathodes disposed in said anode portions and spaced in coaxial relation to the internal surfaces thereof, a cylindrical connecting member of smaller diameter extending between said cathodes and coaxially related to the intermediate portion of said casing, a central support extending through said cathodes and said connecting member, a heater element within each cathode connected to said support and the respective cathode, a perforate grid located between each cathode and anode portion, a tubular metallic member extending between oppositely disposed grids and having a diameter the same as said grids, said latter member being coextensive with said connecting member and said intermediate portion, insulating spacing means supporting said members in coaxial relation to said intermediate portion, and conductors extending through said intermediate portion and connecting said members and said central support, in the same plane as said insulating means but out of contact therewith.

15. A push-pull oscillation generator comprising coaxial cathodes, grids and anode elements in opposed relation, and coaxial hollow metallic coupling members interconnecting opposed similar elements, said members progressively increasing in diameter from the inner coaxial member and forming cavity resonators coupling adjacent elements at opposite ends in cooperating relation, conductors extending through said members in isolated relation and positioned in a medial plane thereof, and an output loop connected to one of said conductors, said loop being located within the area between the intermediate and outer coupling members.

16. An ultra-high frequency reciprocal generator of high power comprising a cylindrical metallic enclosing vessel having an external anode portion at each end thereof, a cylindrical grid-like electrode within each anode portion in coaxial relation thereto, a continuous metallic sleeve extending linearly between opposite electrodes and coextensive with said metallic vessel intermediate the end anode portions, a plurality of spaced radial insulating arms secured between said metallic vessel and said sleeve, a cylindrical box-like cathode disposed within said electrode at each end of said vessel, a metallic coupling sleeve extending between opposite cathodes, a plurality of spaced radial insulating arms interconnecting said sleeves, a support rod extending axially through said cathodes and coupling sleeve, a coiled heater element within each cathode and attached at one end to said rod and at the other end to said coupling sleeve, a plurality of metallic nipples secured to said vessel in a medial plane around a portion of the periphery of said vessel, conductors extending through said nipples and connected to said rod, sleeves and vessel, respectively, and insulating closures sealing said conductors and nipples to maintain a high vacuum within said vessel.

17. An ultra-high frequency reciprocal generator of high power comprising a cylindrical metallic enclosing vessel having an external anode portion at each end thereof, a cylindrical grid-like electrode within each anode portion in coaxial relation thereto, a continuous metallic sleeve extending linearly between opposite electrodes

15

and coextensive with said metallic vessel intermediate the end anode portions, a plurality of spaced radial insulating arms secured between said metallic vessel and said sleeve, a cylindrical box-like cathode disposed within said electrode at each end thereof, disc heat shields at opposite ends of each cathode, a metallic coupling sleeve extending between opposite cathodes, a plurality of spaced radial insulating arms interconnecting said sleeves, said latter arms being staggered with respect to the arms between said metallic vessel and said continuous sleeve, a support rod insulated from said cathodes and extending axially through said cathodes and coupling sleeve, a coiled heater element within each cathode being attached at one end to said rod and at the other end to said coupling sleeve, a plurality of metallic nipples hermetically sealed to said vessel in a medial plane around a portion of the periphery of said vessel, conductors extending through said nipples, and insulating closures sealing said conductors to said nipples, one conductor extending through said sleeves and being connected to the mid-point of said rod, another conductor extending through said continuous sleeve and being

16

connected to said coupling sleeve, and the remaining conductors being connected to said vessel and said continuous sleeve.

CLIFFORD E. FAY.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,167,201	Dallenbach	July 25, 1939
2,228,939	Zottu et al.	Jan. 14, 1941
2,186,127	Samuel	Jan. 29, 1940
1,979,668	Boddie	Nov. 6, 1934
2,170,653	Buschbeck	Aug. 22, 1939
2,044,369	Samuel	June 16, 1936
2,063,341	Samuel	Dec. 8, 1936
2,163,247	Samuel	June 20, 1939
2,163,244	Kircher	June 20, 1939
2,108,539	Lindenblad	Feb. 15, 1938

FOREIGN PATENTS

Number	Country	Date
269,169	Great Britain	Aug. 30, 1928