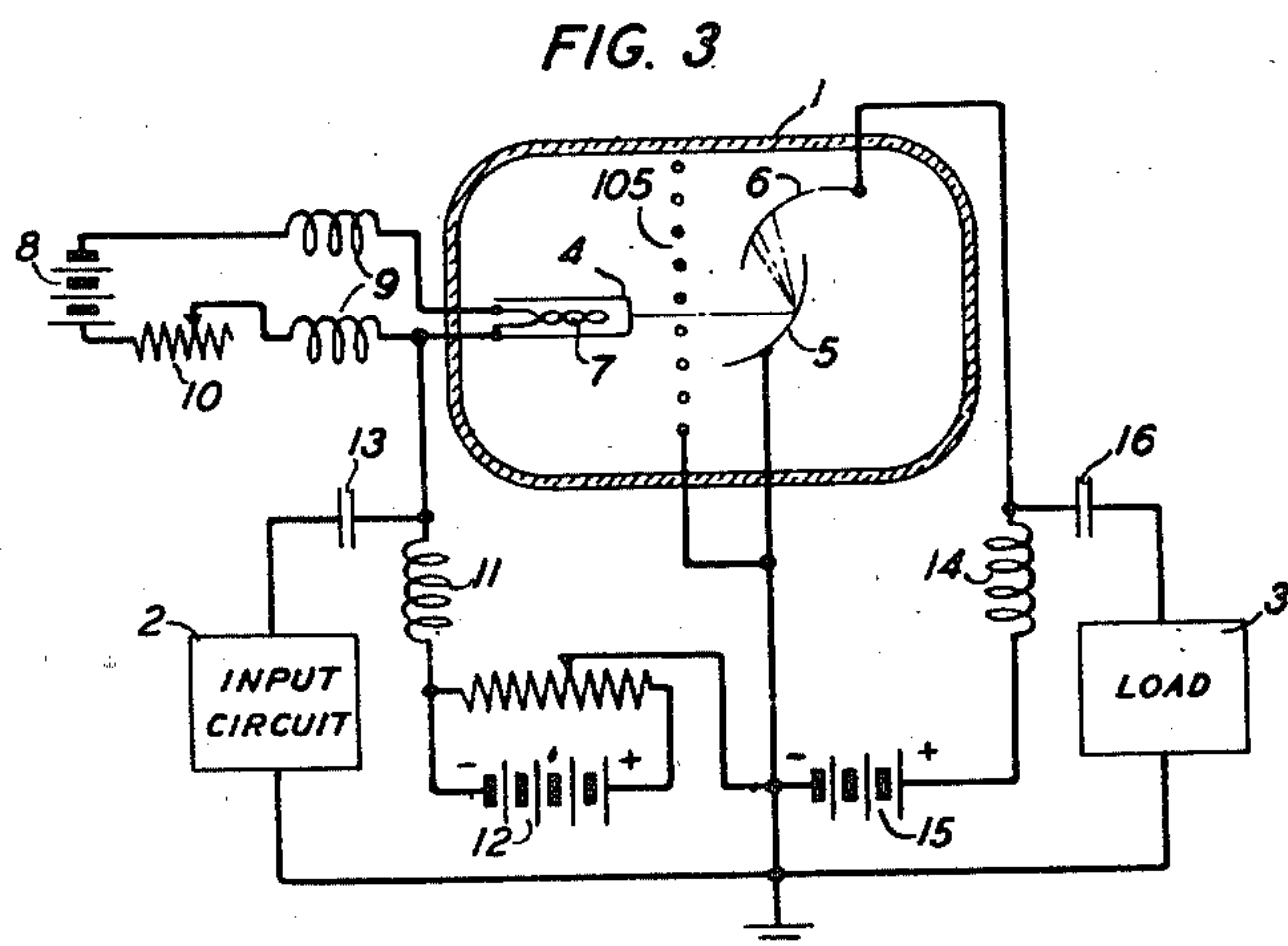
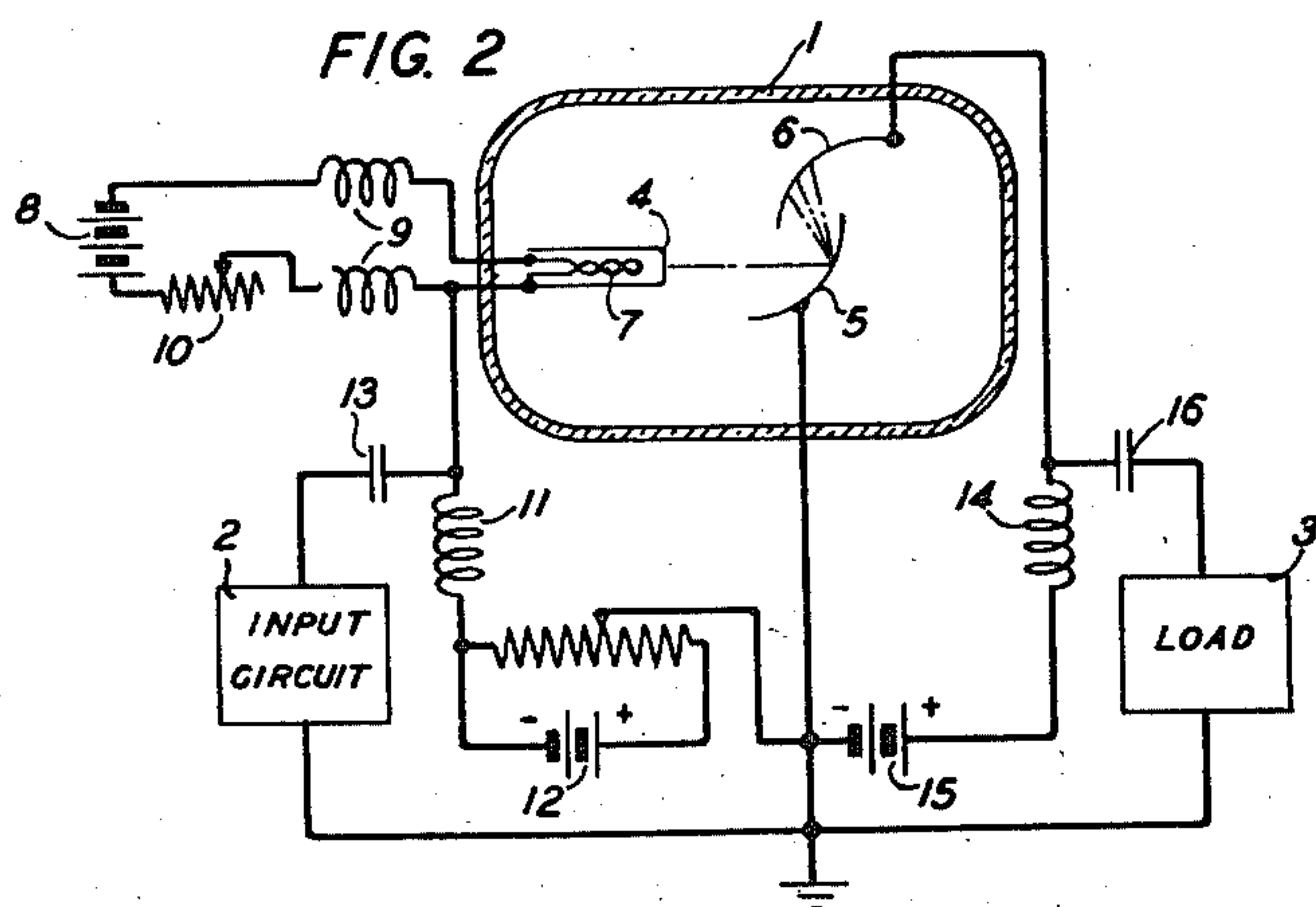
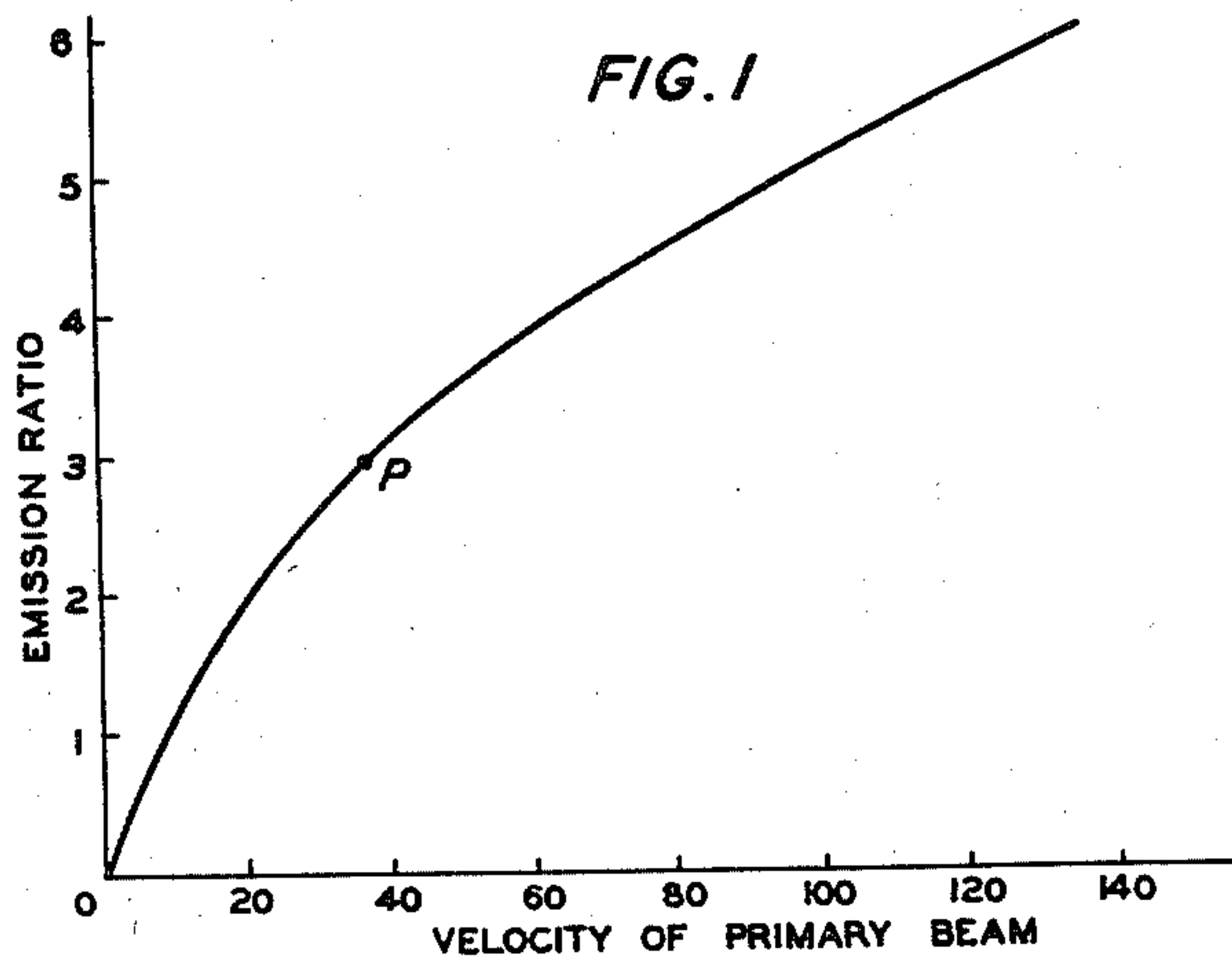


Feb. 25, 1947.

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ELECTRONIC APPARATUS
Filed Jan. 7, 1941

2,416,302

4 Sheets-Sheet 1



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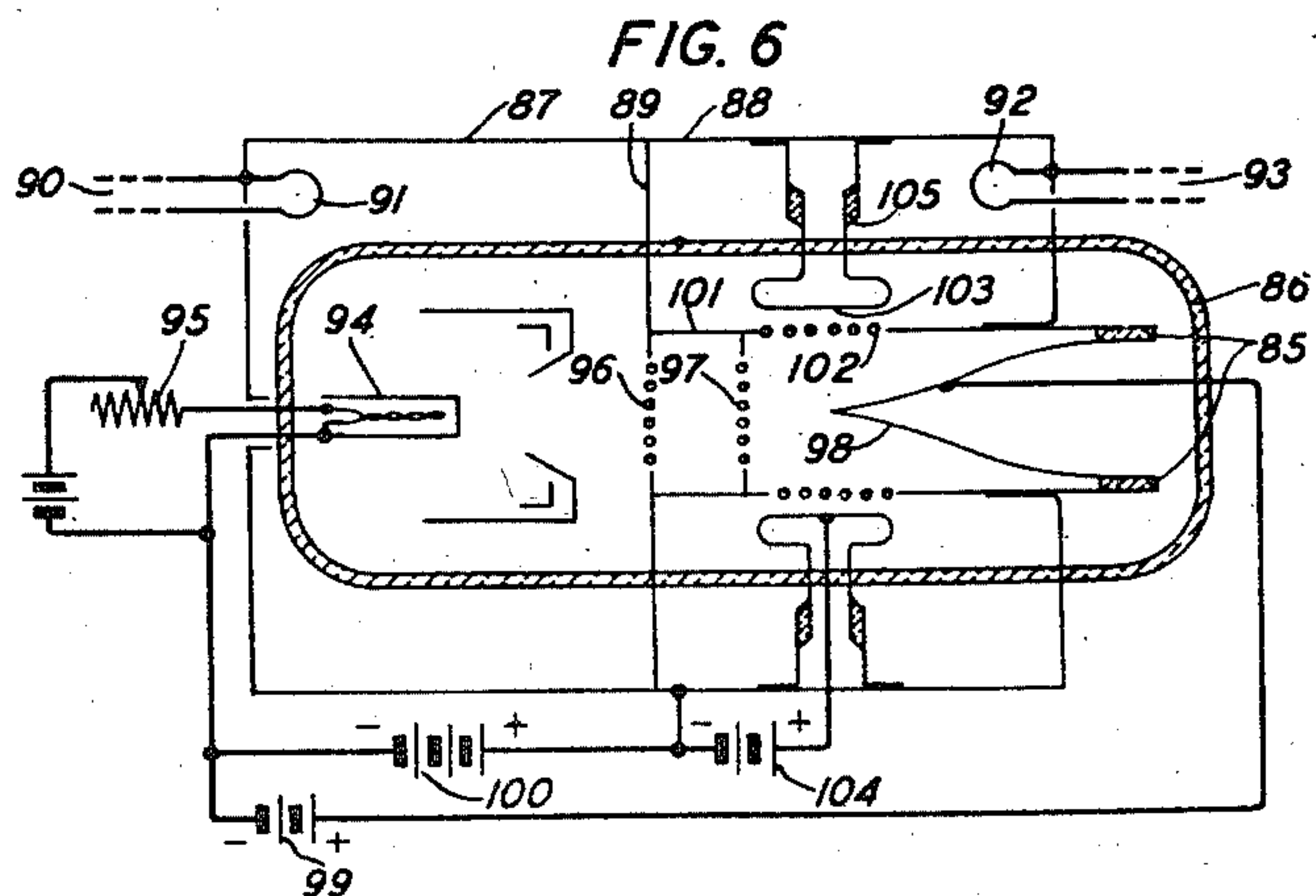
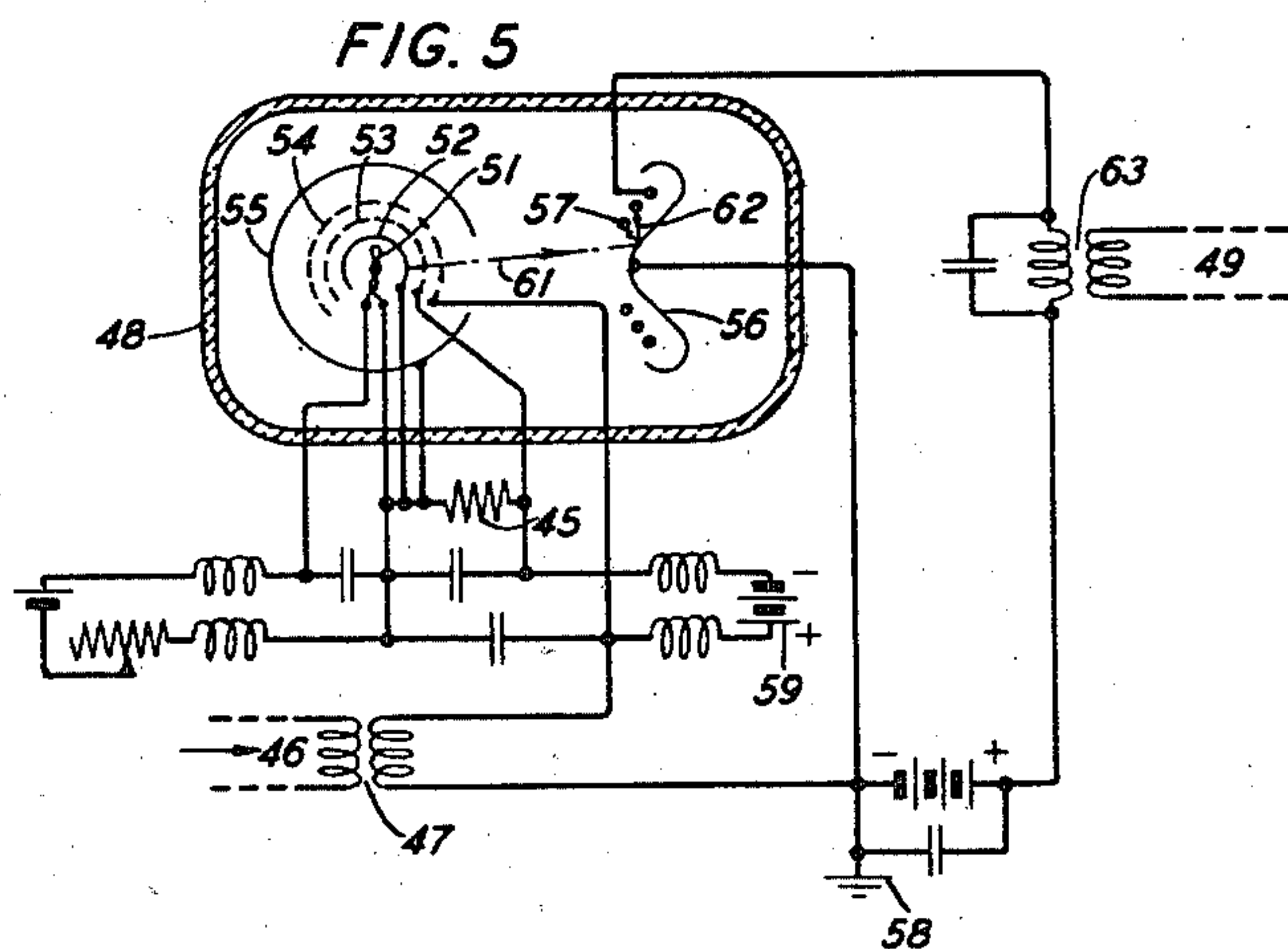
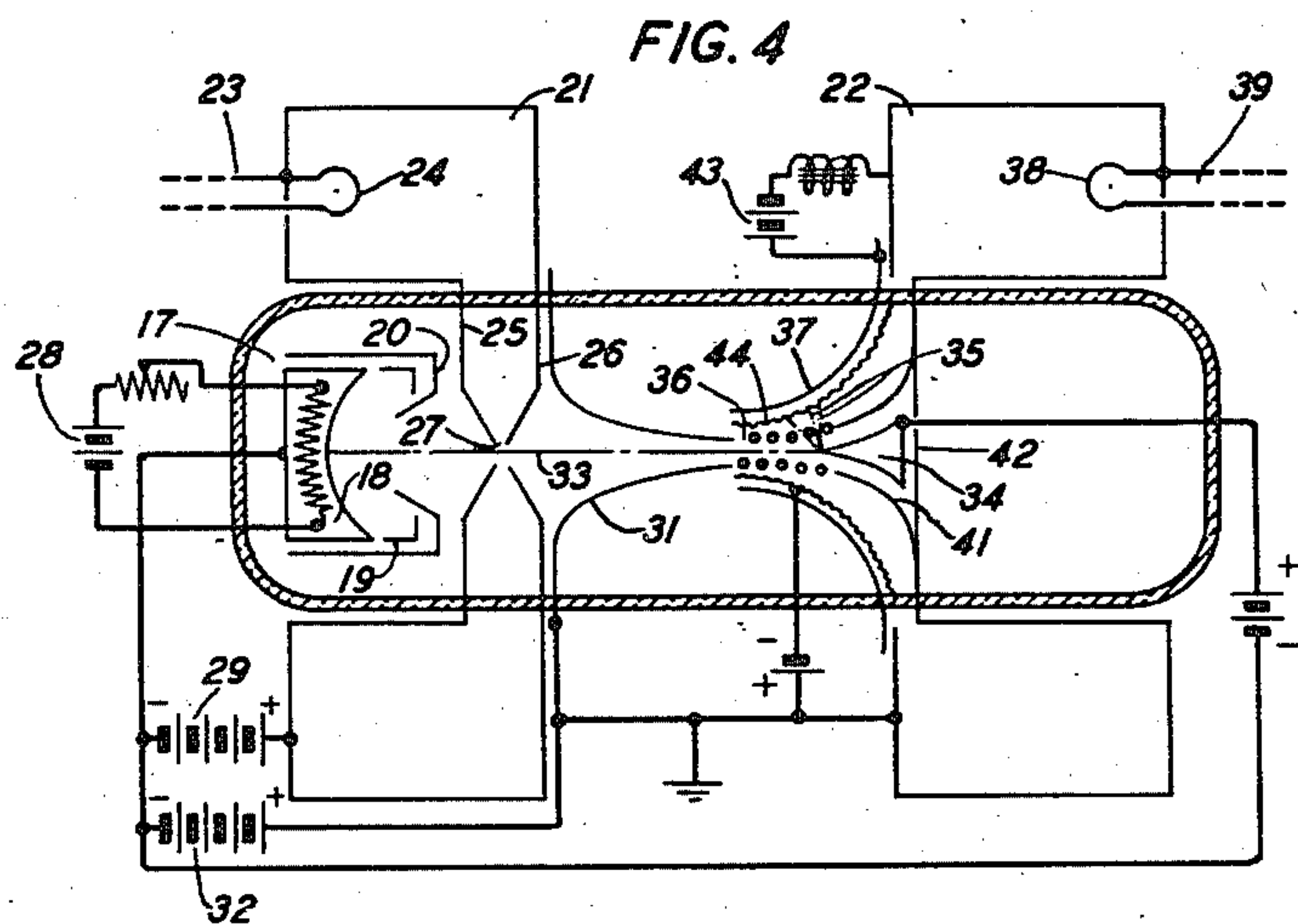
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ELECTRONIC APPARATUS

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4 Sheets-Sheet 2



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2,416,302

ELECTRONIC APPARATUS

Filed Jan. 7, 1941

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FIG. 7

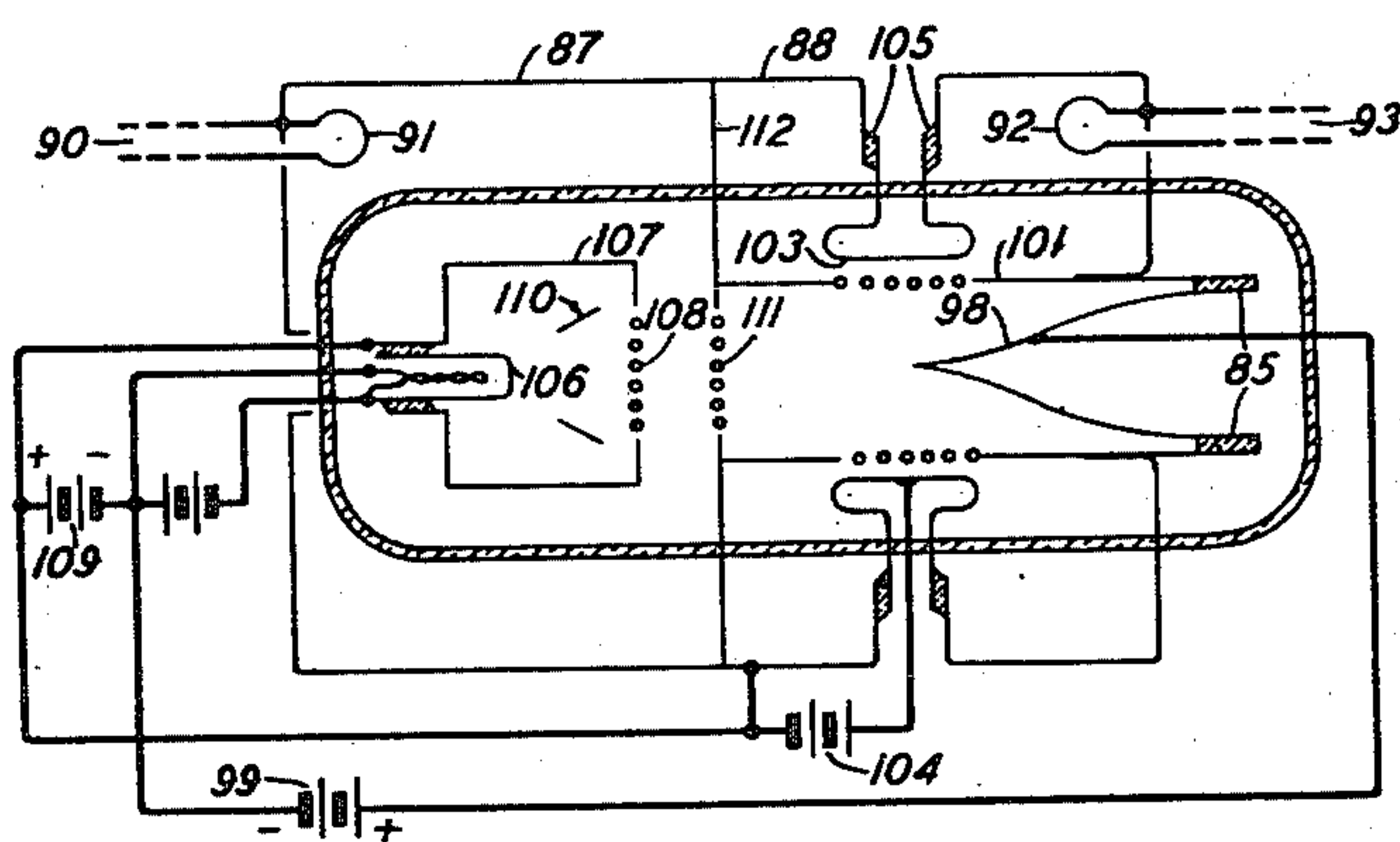


FIG. 8

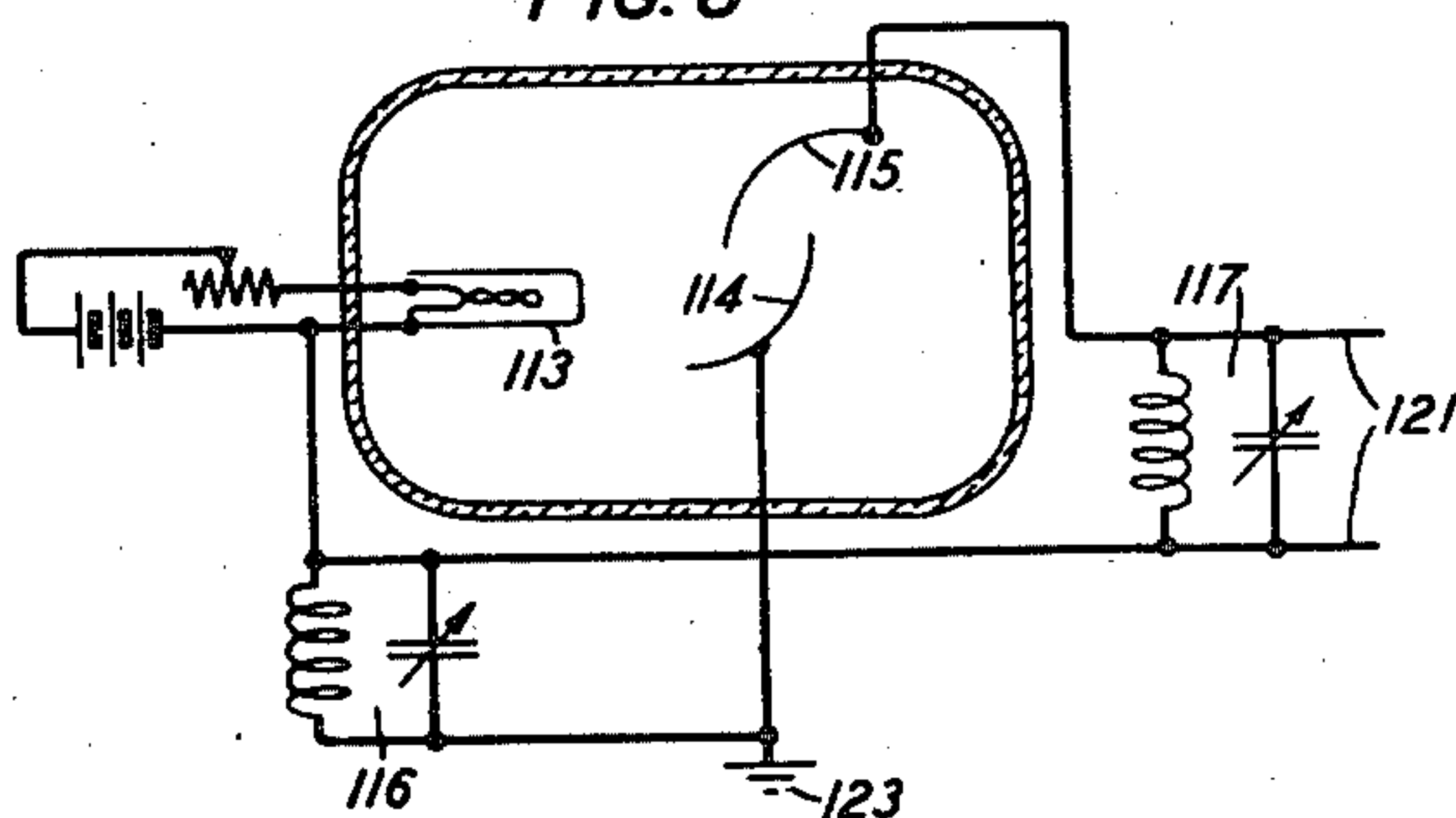
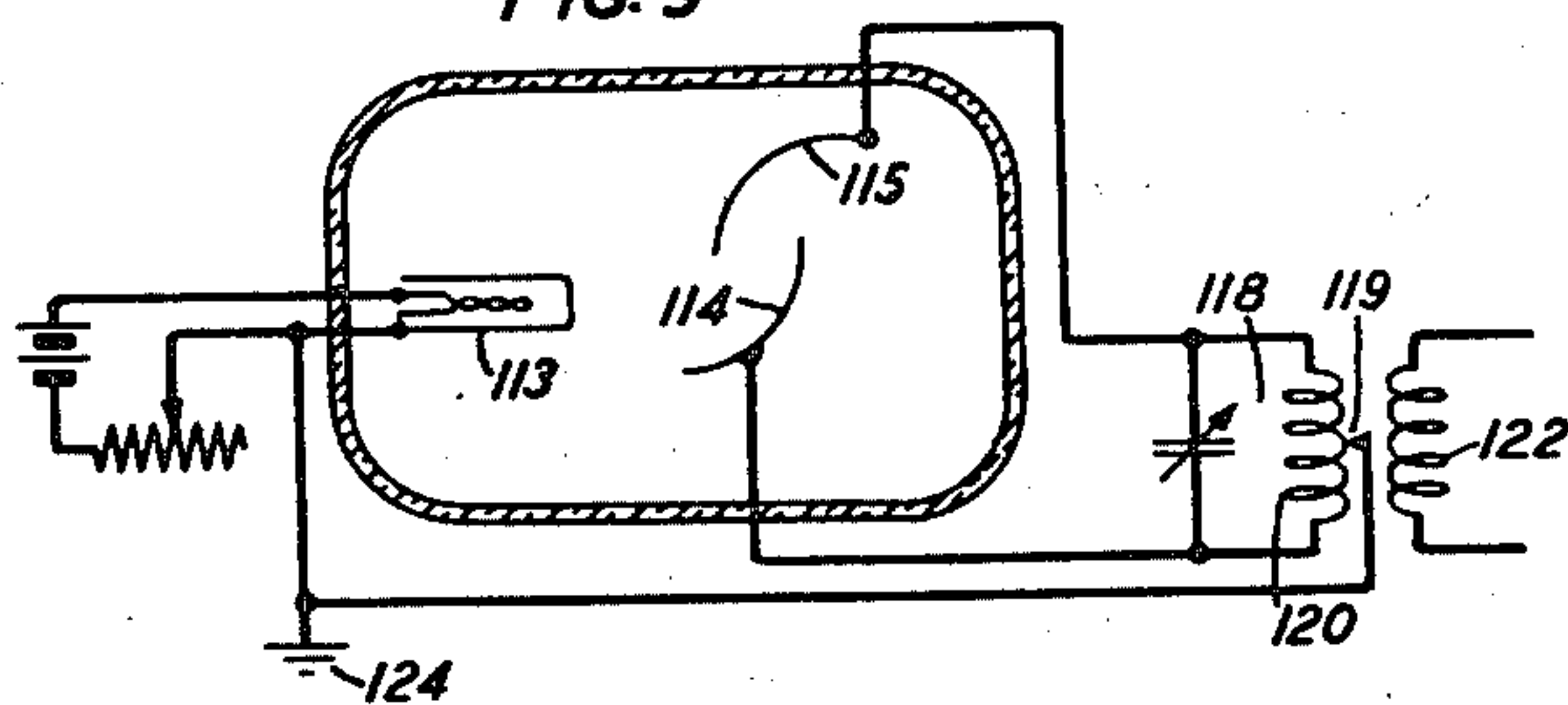


FIG. 9



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ELECTRONIC APPARATUS

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FIG. 10

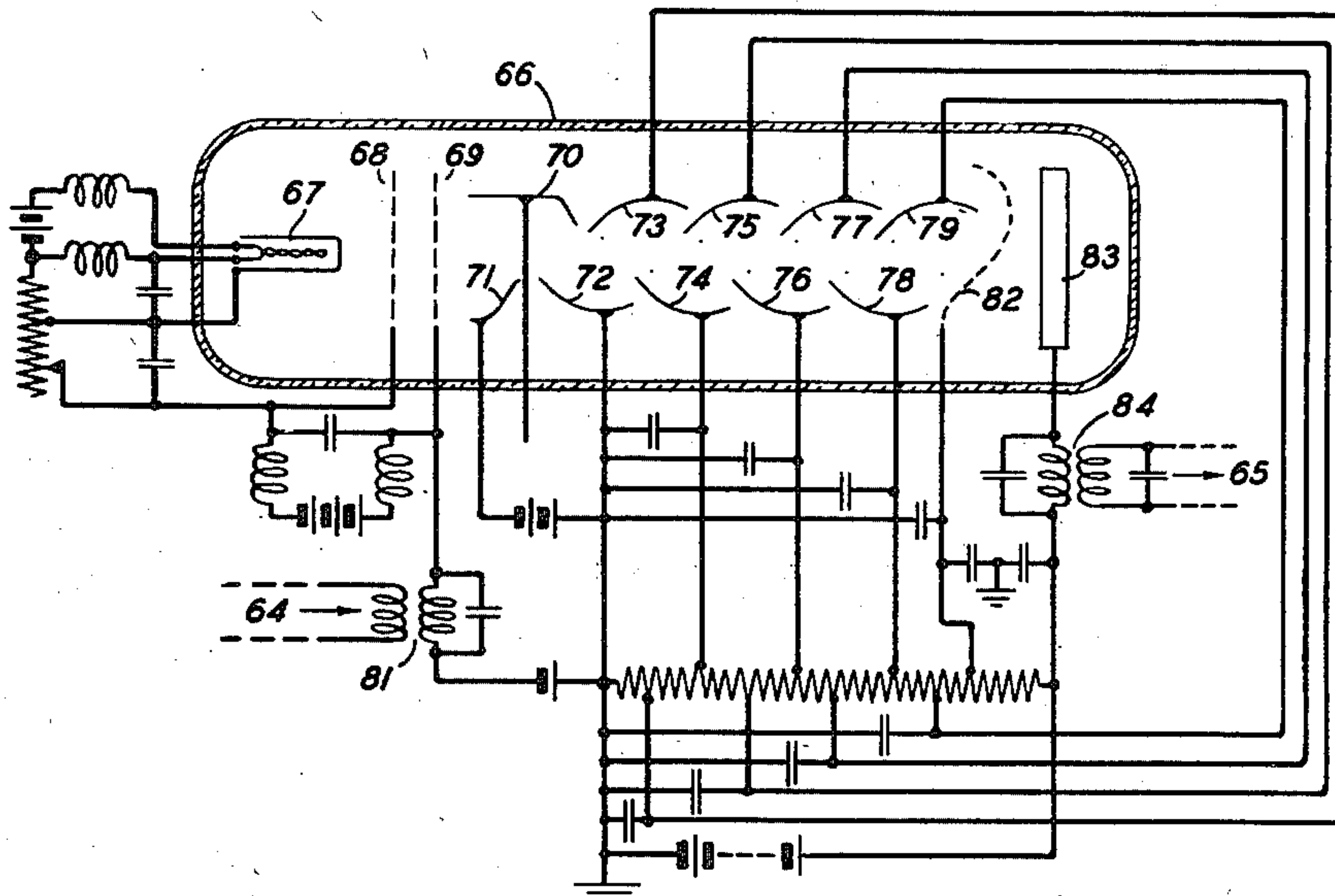
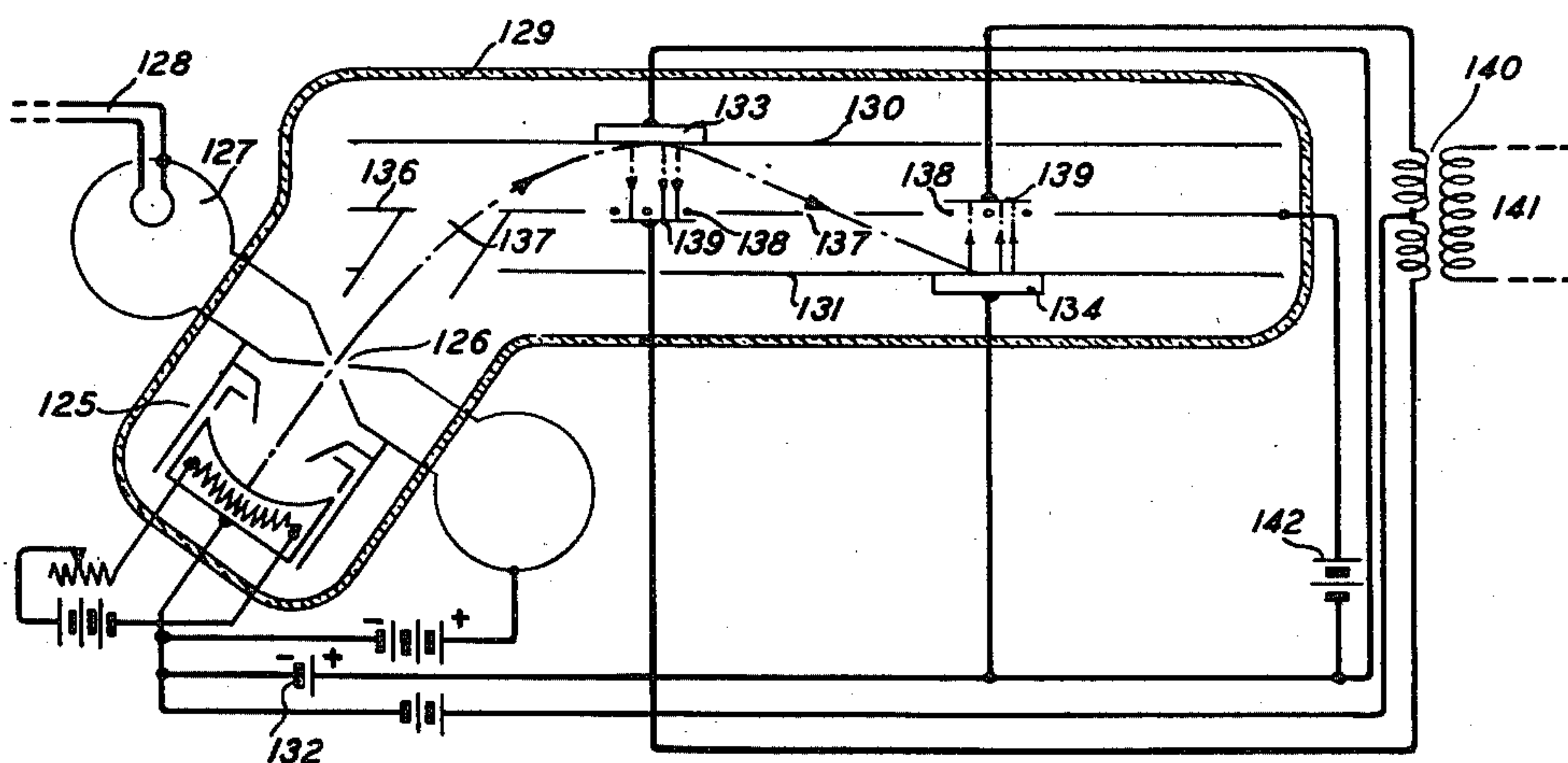


FIG. 11



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UNITED STATES PATENT OFFICE

2,416,302

ELECTRONIC APPARATUS

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Application January 7, 1941, Serial No. 373,417

13 Claims. (Cl. 179—171)

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This invention relates to electronic apparatus and methods for production, amplification and control of electromagnetic waves.

An object of the invention is to increase the transconductance of electronic devices operating with electromagnetic waves in the centimeter wave-length range.

Another object is to provide an electronic type of amplifier which is highly free of critical spacings and consequently suitable for transmission of waves over a wide range of frequencies.

Another object is to utilize the principle of secondary electron emission to produce a density varied beam in response to a velocity varied electron stream incident upon a secondary electron emitter.

In accordance with this invention, the current of an input circuit which may be that of a radio receiving system, an amplifier, an oscillator or other electrical translating device is caused to set up an electromagnetic field in the path of an electron stream of constant magnitude in such manner as to vary the velocities of the electrons. The resulting velocity varied electron stream is utilized to excite by impact a secondary electron-emitting surface which has the property of yielding in response to an electron impact a number of secondary electrons which depends upon the velocity of the impinging primary electron. The secondary electron beam is density varied and, accordingly, may be used to excite an output system or to energize a load circuit.

In one embodiment of the invention a multistage electron multiplier is employed to first produce a density varied beam and thereafter to augment it. In another, the primary stream is impelled toward a plurality of secondary emitters at successive points along the trajectory so that primary electrons not collected by the first secondary electron emitter may pass on to impinge upon and excite the second.

Other features and aspects of the invention will be apparent from the following detailed specification and appended claims taken in connection with the accompanying drawing in which:

Fig. 1 is a graph presenting the relationship between secondary electron emission ratio as ordinates and velocity of the impinging primary beam as abscissae;

Fig. 2 is a schematic diagram of an amplifying device embodying the invention;

Fig. 3 shows the application of a screen grid to the electron discharge device of Fig. 2;

Fig. 4 is a diagram of an alternative amplifier

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for very short waves where transit times are important;

Fig. 5 illustrates another embodiment of the invention utilizing a standard type of thermionic cathode secondary emission tube;

Figs. 6 and 7 show modifications of the amplifier of Fig. 4;

Fig. 8 illustrates an oscillator in which a velocity varied electron stream is utilized in connection with the secondary electron emitter to excite a density varied stream;

Fig. 9 is a modification of the oscillator circuit of Fig. 8;

Fig. 10 relates to an alternative embodiment of the invention utilizing a multistage electron multiplier, and

Fig. 11 presents an amplifying system in accordance with the invention in which the primary electron stream is associated with a plurality of secondary electron emitters which it passes in turn.

The number of electrons emitted by a secondary electron emitter when excited by the impact of a primary electron depends to an extent upon the material which constitutes the surface of the emitter. For all such materials, however, the emission ratio, that is the number of secondary electrons emitted for each impinging primary electron, varies with the velocity of the incident primary electron. A typical characteristic of the emission ratio relative to primary beam velocity is one in which the emission ratio increases rather steeply at first and then with a less rapidly rising rate until it reaches a maximum and finally begins to fall off. A portion of such a characteristic for a caesium-caesium oxide-silver surface, substantially as disclosed in the paper by Zworykin, Morton and Malter in the Proceedings of the Institute of Radio Engineers for March 1936, is shown in Fig. 1.

It is apparent that if the secondary emitter, the characteristic of which is portrayed in Fig. 1, were to be excited by an electron stream of constant intensity, that is, having the same number of electrons per unit of time but of varying velocity that the secondary emission from the emitter would vary in intensity in accordance with the instantaneous velocity of the impinging electrons. The present invention takes advantage of this fact to convert the energy of a velocity-varied electron stream of primary electrons into that of a density varied beam of secondary electrons. As the characteristic of Fig. 1 makes evident, the change in emission ratio for a given change in primary beam velocity is high at very low volt-

ages. Moreover, there is an advantage in utilizing a low velocity impinging beam for the reason that bombardment by high velocity beams tends to cause deterioration of secondary electron-emitting surfaces and to cause them to be short-lived. However, in order to avoid space charge effects near the surface of the secondary emitter, it is necessary for the primary electrons to have an appreciable velocity when they hit the surface. A satisfactory compromise may be had by operating with the mean velocity of the impinging electrons at some point such as P when the primary electrons have a velocity corresponding to about 40 electron volts. The slope of the characteristic is sufficiently great to enable relatively small changes in velocity to produce appreciable changes in secondary electron emission and the energy of the impinging electrons is sufficiently low to prevent premature destruction of the secondary electron-emitting surface.

There will be a tendency for the primary electrons to be deflected away from the secondary emitter cathode by the field between the secondary emitter cathode and the collector. For this reason the shape and spacing of the electrodes together with the potentials applied between the various electrodes should be such as to reduce this effect to a minimum.

In the diagram of Fig. 2 which presents an electric wave amplifier, an electron discharge device comprising the evacuated container 1 is associated with an input circuit 2, which may be a local source of oscillations or an antenna of a radio receiver, and a load 3, connected to the output terminals of the device 1, to which the amplified or intensified waves are transmitted. The discharge device 1 includes a thermionic cathode 4, a secondary-emitting cathode 5 and an anode or electron collector 6. Associated with the cathode 4 is a heater 7 supplied with heating energy from a source 8 through choke coils 9, which serve as high impedances for energy of the frequency for which the system is adapted, and a controlling potentiometer 10. The potentiometer is so adjusted that the temperature of the cathode 4 is limited in order to operate the device at current saturation so that the total electron emission from the cathode with the given space current electromotive force is practically independent of increase of the electromotive force between the cathode and the secondary electron-emitting surface 5. The cathode 4 and the secondary electron emitter 5 are connected by an external circuit including high impedance choke 11 and the source 12 of the primary electron stream. The input circuit 2 is connected through a capacitance 13 directly between the terminals of the cathode and the secondary electron emitter. Secondary emitter 5 and the electron collector or anode 6 are connected by an external circuit including the high impedance choke 14 and the space current source 15. The load 3 is connected through the series capacitor 16 directly between the terminals of the secondary emitter 5 and the electron collector 6.

In operation with the rheostat 10 properly adjusted to effect temperature saturation of the cathode and with the space current source 12 arranged to impress between the cathode 4 and secondary electron emitter 5, an electromotive force approximately that corresponding to the abscissae of the point P of Fig. 1, the normal velocity of the primary stream of electrons emitted from cathode 4 and incident upon the secondary electron emitter will be a function of

the square root of the abscissae of the point P of Fig. 1. For each electron incident upon the secondary electron emitter something like three secondary electrons will be emitted in the direction of the electron collector 6. If, now, an alternating electromotive force be impressed by the input circuit 2 between the cathode 4 and secondary electron emitter 5 the potential difference between these points will rise and fall accordingly and the operating point will likewise rise above and fall below the point P in step with the impressed potential difference. As the potential difference reaches the maximum, the secondary beam of electrons passing from the emitter 5 to the collector 6 will likewise reach a maximum. When the potential difference is at a minimum, the secondary beam will fall to its minimum value. It will, therefore, be understood that the beam of electrons passing from emitter 5 to anode 6 is density varied in accordance with the instantaneous electromotive force of the input circuit. The rising and falling of the beam between the electrodes 5 and 6 gives rise to an external output circuit electromotive force between those electrodes which, because of the high impedance of the choke coil 14, is substantially wholly expended in driving alternating current through the path including the load coupling capacitance 16 and the load 3.

In order to prevent coupling between the input and output due to external circuits which might result in deleterious feedback it is advantageous to connect the input circuit directly between the primary emitter and the secondary emitter and to connect the output circuit directly between the secondary emitter and the collector. This permits these two external circuits to be designed to have negligible mutual impedance. It also permits grounding of the secondary emitter, as shown, as may frequently be desirable.

In the discussion of the apparatus of Fig. 2 it has been assumed that the physical distance between the cathode 4 and the secondary electron emitter 5 taken in connection with the frequency of the electric waves impressed by the input circuit 2 upon the device 1 is so small as to permit transit time to be neglected. Under these circumstances the primary electron stream passing from the cathode 4 to the secondary emitter 5 will be of substantially constant density.

Fig. 3 illustrates an amplifier circuit identical with that of Fig. 2 except that the electron discharge device is provided with a screen electrode 105 between the primary emitter 4 on the one hand and the collector 6 and the variable secondary stream from secondary emitter 5 to collector 6 on the other hand. This screen reduces the internal capacity between the cathode 4 and the internal secondary emission stream electrodes and thus provides an additional safeguard against undesirable feedback. The screen electrode may be polarized at about the same potential as the secondary emitter, as illustrated, or it may be at a somewhat less positive potential conforming generally to the normal space potential to its position in the absence of such a screen electrode.

For ultra short wave applications where transit times are important it is necessary to use a structure that is somewhat different from those of Figs. 2 and 3. Such a structure is shown in Fig. 4 in which an evacuated container includes an electron gun 17 having a temperature limited cathode 18, the electron-emitting surface of which is arcuate or spherical in contour, focusing member 19 and an anode 20. The details of this

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gun are not shown as they form no part of the invention. It should be understood, however, that the electron gun may be of any well-known type or it may be of the type illustrated in Parker-Samuel application, Serial No. 327,826, filed April 4, 1940, which became Patent No. 2,268,165, dated December 30, 1941. Associated with the discharge device are resonant input and output chambers 21 and 22 respectively which consist of closed annular shells of conducting material. An input circuit 23 conducts incoming electrical waves to a loop 24 terminating the input circuit within the chamber 21. The chamber 21 extends into the evacuated container, its central portion comprising the circular conducting discs 25 and 26 which are sealed through the discharge device near their outer margins and which taper inwardly at their central portions at which they are provided with openings constituting the velocity varying gap 27 which is axially aligned with the central axis of the electron beam emitted from the cathode 18. A source 28 supplies heating current to the heater of the cathode 18. A source 29, of an electromotive force of 500 to 2000 volts, depending upon the gun design, is connected between the cathode 18 and the resonance chamber 21 to accelerate the electron stream to an appropriate velocity for electron velocity variation by the electromagnetic field within the gap 27 through which the electron stream passes. Preferably, the transit distance through the gap 27 is so related to the resonance frequency of the chamber 21 and the velocity of electrons arriving at the gap that electron transit through the electromagnetic field at the gap occurs in a period of less than one-quarter of the resonance frequency cycle. The electron stream emerging from the gap 27 with the velocities of its electrons varied in accordance with the field within the gap proceeds within a shielding member 31 which is polarized positively by the source 32 to a potential of the order of the velocity of the electrons in the beam, e. g., of approximately 500 volts.

The shield 31 continues physically as a grid structure 36 and finally a solid conducting shielding portion 41, the grid 36 and portion 41 accordingly having the same potential as shield 31. The electron stream proceeding along the broken line path 33 finally impinges upon a wedge-shaped secondary electron emitter 34. The emitter 34 is at a relatively low potential of the order of +50 to +100 volts with respect to cathode 18 in order that the electrons arriving at and impinging upon its surface may most efficiently excite secondary electrons, as explained in connection with Fig. 1.

The most efficient operation requires that the transit distance through the gap 27 be small, namely, less than about one-quarter of a wavelength. However, it is possible to obtain operation at shorter wave-lengths (for the same physical structure) when the transit angle for the gap is between about 7 and 11 radians. The best value to use depends upon such factors as space charge effects in the beam and the ratio of gap length to diameter of gap electrode openings. The primary electrons are collected by the secondary emitter 34 and give rise to the emission of secondary electrons along the paths 35. The number of secondary electrons, as has been explained in connection with Fig. 1, depends upon the velocity of the incident primary electrons. The secondary electrons in traversing the space between the grid 36 and the collecting anode 37

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react with the electromagnetic field of the resonance chamber 22 of which grids 36 and 44 constitute a terminating gap and deliver energy thereto. Within the chamber 22 is a loop 38 connected to the outgoing circuit 39 from which the amplified electromagnetic waves may be withdrawn.

The spacing between the gap 27 and the secondary emitter 34, although indicated as relatively large in the drawing, will, in practice, be kept as small as possible consistent with good shielding between the input and output sections of the tube. This shielding is effected by the screen 31 and its electrical continuations including the grid 36 and the conducting surfaces 41 and 42 which are preferably all at the same positive potential. The collector 37 is maintained by the source 43 at a potential sufficiently high with respect to that of the grid 36 and the resonance chamber 22 to prevent secondary emission from the collector to the screen 36. It is possible, however, to operate the collector 37 at a potential lower than that of the screen 36 by interposing a suppressor grid 44 polarized to about the same potential as the secondary emitter 34 or slightly higher between the grid 36 and the collector 37. Although suppressor grid 44 is sufficiently close as its margin to the wall of chamber 22 to constitute an extension thereof for high frequency oscillations it is insulated therefrom. The entire structure is made as nearly as possible self-shielding by minimizing the possibility of high frequency potential differences along its external surfaces. Accordingly the adjacent parallel discs of members 26 and 31 are sufficiently close to constitute a relatively large high frequency capacitance. The same is true of the closely adjacent portions of collector 37 and chamber 22 and of the base of target 34 and the closely adjacent surface of member 42.

A difficulty commonly encountered in secondary emission devices that use a hot cathode is contamination of the secondary surface by material from the cathode. This difficulty can be surmounted by using a gun structure in which the cathode is shielded from the secondary surface. An alternative is to use a pure metal such as copper or silver for the secondary surface and to maintain this surface at a high enough temperature to keep it clean. When a pure metal is used as the secondary cathode the ordinates shown on Fig. 1 are different in that the maximum emission ratio is between 1.0 and 2.0. At the point corresponding to P the ratio might be of the order of 1.0.

Fig. 5 illustrates an alternative of the circuit of Fig. 2 in which instead of a temperature-limited cathode to supply the constant density electron beam an ordinary indirectly heated cathode with a screen grid structure is employed. Secondary emission devices employing this type of structure are disclosed by Jonker and Overbeek at pages 150 to 156, inclusive, of the Wireless Engineer, March 1938, vol. 15, No. 174. As shown, an input circuit 46 is connected through a transformer 47 to input terminals of an electron discharge device 48 to the output terminals of which is connected the output circuit 49. The discharge device 48 comprises an evacuated container enclosing a heating element 51, indirectly heated cathode 52, a control grid 53, a screen grid 54, a focusing deflector 55, a secondary electron emitter 56 and a grid form electron collector 57 interposed between the primary cathode 52 and the secondary electron emitter 56. In this instance as in Fig. 2,

the secondary electron emitter 56 is directly grounded as at 58. The central portion of the cathode 56 is not coated with electron-emitting material but the region directly beneath the electron collector 57 is so coated. Primary electrons from the heated cathode 52 are accelerated by the potential of the screen grid 54 which is positively polarized by the source 59 and thus electrons passing through the screen grid 54 along a path such as the broken line 61, impinge upon the secondary electron-emitting surface 56, to cause secondary electron emission along the paths 62 to the collector electrode 57. The function of the resistance 45 connected between the cathode 52 and control grid 53 is to help maintain the current leaving the screen structure at a constant value. Since the velocities of the impinging primary electrons have been varied by the electric field between the electrode 54 and the secondary-emitting surface 56 and that electric field is a function of the instantaneous electromotive force impressed from the input circuit 46, the velocities of the primary electrons impinging upon the secondary emitter 56 will vary with the current of the input circuit 46. As has been explained in connection with the previous figures the resulting secondary electron emission from the secondary emitter will be density varied. It transpires, therefore, that the weak incoming currents of input circuit 46 have given rise to greatly augmented alternating currents in the external circuit of the collector 57. Energy of these augmented currents is transferred by the transformer 63 to the output circuit 49.

The cathode control grid and screen grid structures of Fig. 5 are all connected together for alternating currents by by-pass condensers. These electrodes when used in this manner produce a current passing through the screen electrode 54 which is of constant density, (similar to that of a temperature limited cathode). The input field between the screen electrode 54 (and whole inner structure) and the secondary-emitting surface 56 produces the velocity variation of the electrons that leave the inner structure and pass to the secondary-emitting surface.

Fig. 6 illustrates an amplifier which is functionally quite similar to that of Fig. 4. It comprises an evacuated container 86 associated with a resonant conducting input chamber 87 and a resonant output chamber 88, which have a common wall 89 comprising a disc which passes through the container 86. An input circuit 90 is terminated in a coil 91 within the input chamber 87 to effect a coupling between the input circuit and the field within the resonant chamber. In similar fashion, coil 92 of the output circuit 93 is introduced within the resonant output chamber 88. An electron gun 94 which may be similar in all respects to the gun 17 of Fig. 4 is located within the envelope 86 in the input chamber portion. The temperature of the cathode of the gun 94 is limited by means of the heating current potentiometer 95 to restrict the primary electron emission to a constant magnitude as in the case of Fig. 4. The electron beam from the gun 94 passes through a central screen or grid portion 96 of the wall 89 and a grid-like shield 97 in line therewith before impinging upon the conical-shaped secondary electron emitter 98. Electron emitter 98 is insulated from wall 101 by dielectric 85, the capacitance between members 98 and 101 being relatively large at the operating frequency to provide a low impedance connection between them. A source 99 of unidirectional electromotive force is connected between the

electron gun 94 and the secondary emitter 98 to set up an electron impelling field therebetween. A source 100 is employed to polarize the resonant chamber 87 and its grid 96 positively with respect to the gun 94. Within the resonant chamber 88 is an internal cylindrical wall 101 which may be concentric with the chamber itself. The cylindrical wall 101 supports the shield 97 and also includes along a portion of its length opposite the secondary emitter 98 a cylindrical grid 102 through which secondary electrons from the emitter 98 pass to a cylindrical collector 103. The collector 103 is positively polarized by a source 104 and must, therefore, be insulated from the resonant chamber 88 as indicated at 105. The capacitance between it and the supports integral with the resonant chamber at dielectric 105 is relatively high at the operating frequency to effectively connect the two for high frequency purposes. Electrons emitted by the gun 94 and accelerated by the unidirectional field between the gun and the screen 96 experience a varying acceleration on their transit toward the screen in accordance with the instantaneous field existing within the resonant input chamber 87 as determined by the energy supplied thereto from input circuit 90. The velocity varied electrons pass through the screen 96 and also through the shield 97 on their way to the secondary emitter 98. The shielding members 101 and 97 serve to maintain the velocity varied electron stream substantially unaffected by the field of the collector 103. Upon impact on the emitter 98 the velocity varied primary electrons release a number of secondary electrons depending upon the impact velocity of the primary electrons. The secondary electrons pass through the shield 102 to the collector 103 and in their transit between these members react with the electromagnetic field within the chamber 88 imparting energy thereto. In this manner the weak incoming energy of input circuit 90 is amplified and is delivered from the resonant output chamber 88 to the output circuit 93.

Fig. 7 illustrates diagrammatically a high frequency amplifier which is, in general, similar to that of Fig. 6. Corresponding parts are similarly numbered and have the same function as in Fig. 6. In lieu of the electron gun 94 of Fig. 6 there is employed an electron-emitting assembly like that of Fig. 5 in which instead of employing a temperature limited cathode, a screen grid is used. The cathode proper 106 with its heater is enclosed within but insulated from a reflector 107, the otherwise open front portion of which is covered by a screen grid 108. The leads to the cathode 106 and other members within chamber 107 pass through insulating sleeves inserted in the walls of the chamber. Source 109 serves to polarize the screen positively with respect to the cathode. Focusing members 110 suitably polarized by external sources, which are not shown, serve as in the case of the elements 19 and 20 of Fig. 4 to direct the beam of electrons through the screen 108. The structure so far described serves to emit through the screen 108 a beam of electrons of constant intensity, that is, of substantially uniform number with respect to time. The constant intensity beam, as in the case of Fig. 6, is subjected to the steady unidirectional field between the grid 108 and a grid 111 constituting a central portion of the wall 112 separating the input and output chambers 87 and 88. Upon this unidirectional field is superimposed a variable electromagnetic field set

up by the energy incoming from input circuit 90. Accordingly, the beam passes through the grid 111 as a variable velocity beam. The operation of this apparatus is in other respects identical with that of Fig. 6.

The systems of the Figs. 4, 5, 6 and 7 lend themselves to symmetry of the apparatus with respect to the longitudinal central axis of the tube. Accordingly, the various electrodes and chambers of these systems may be understood to have circular or cylindrical contours.

Fig. 8 illustrates an oscillator embodying certain principles of this invention in which a primary source of electrons 113 which may specifically be of a temperature limited type like that of the electron gun 17 of Fig. 4 emits electrons which are impelled as a velocity varied stream against the active surface of the secondary electron emitter 114 to excite thereat the emission of a density varied stream of secondary electrons toward the collector 115. The details of the polarizing circuits are omitted as they may be identical with those of Fig. 2. Between the primary cathode 113 and the secondary emitter 114 a tuned input circuit 116 is connected and between the emitter 114 and the collector 115 a similarly tuned output circuit 117 is connected. Since the external input and the external output circuit associated with the secondary emitter 114 are electrically coupled through the circuit 116 oscillations will be produced of a frequency dependent upon the tunings of the external circuits.

Fig. 9 is an alternative of the circuit of Fig. 8 in which the secondary emitter 114 and the electron collector 115 are connected to the electrically most remote terminals of a variable tuned circuit 118 while the primary cathode 113 is connected by a variable tap 119 to an interior point on the inductance 120 of the tuned circuit. In both Figs. 8 and 9 alternating current output energy may be withdrawn from the circuit by connections to the opposite terminals of the output circuit as indicated at 121 in Fig. 8 or by an output winding 122 coupled to the coil 120 as indicated in Fig. 9.

In Fig. 8, the secondary electron emitter 114 is shown grounded at 123 while in Fig. 9, the primary electron emitter is grounded at 124. It is to be understood, however, that, if desired, the primary emitter may be grounded in lieu of the secondary emitter in the circuit of Fig. 8 and that in Fig. 9, the secondary emitter may be grounded instead of the primary emitter. In case the output is taken directly as in Fig. 8, one terminal of the output should probably be grounded for convenience in operation with other devices.

Fig. 10 illustrates another modification in which an input circuit 64 and output circuit 65 are associated with an electron discharge device 66 having an indirectly heated cathode 67, a fixed potential impedance control grid 68, a highly positive screen grid 69 and a multistage electron multiplier including the focussing members 70 and 71 and the secondary electron-emitting cathodes 72 to 79 inclusive. The primary stream of electrons from the cathode 67 accelerated by the field between the cathode and the high potential screen 69 and maintained at a desired normal intensity by adjustment of the potential impressed upon the impedance control grid 68 passes between the focussing members 70 and 71 to impinge upon the surface of the first secondary electron-emitting cathode 72. The potential of the screen grid 69 with respect to the first sec-

ondary electron emitter 72 which is normally set to some desired normal value by source of potential in the external path connecting grid 69 and emitter 72 is varied in accordance with the electromotive force induced in the secondary winding of transformer 81 in accordance with the weak incoming currents of input circuit 64. The impact velocities of the primary electrons upon the secondary emitter 72 will accordingly vary upwardly and downwardly from some normal value such as that of the point P of Fig. 1, thus giving rise to a density varied beam of secondary electrons which is multiplied by the succeeding stages in the conventional manner until it finally passes from the last secondary electron emitter 79 through the shielding screen 82 to the electron collector 83. A transformer 84, the primary of which is in the external circuit of the electron collector 83 and the secondary of which is connected to the output circuit 65 serves to transfer the highly amplified wave energy to the output circuit.

Fig. 11 illustrates an amplifier in which a primary electron stream emitted from the electron gun 125 is velocity varied at the gap 126 in accordance with the electromagnetic wave field of a resonance chamber 127 associated with the input circuit 128. Within the evacuated container 129 there are included two parallel plates 130 and 131 polarized and held at a common potential considerably lower than that of the resonance chamber 127 by means of the polarizing source 132. Associated with the plates 130 and 131 respectively, are secondary electron-emitting surfaces 133 and 134 at such positions that the velocity varied electron stream issuing from the gap 126 will be deflected and caused to just graze the surface of secondary emitter 133. Some of the electrons will be collected by the element 133. The primary electrons which are not collected by 133 will proceed on toward the element 134 where they are collected. Passing centrally through the container 129 between the plates 130 and 131 is a conducting surface 136 apertured at the two positions 137 to permit transit of the primary stream. At regions laterally opposite the secondary emitters 133 and 134 the central plate 136 is apertured in the form of screens or grids 138. Just behind these grids are secondary electron-collecting anodes 139. The central plate 136 and its grids 138 are polarized by a source 142 to a potential somewhat more positive than the plates 130 and 131. These positive grids facilitate withdrawal of secondary electrons from the region of the secondary emitters 133 and 134. In operation of the device incoming currents in the input circuit 128 build up an electromagnetic wave field in the resonance chamber 127 tuned to the desired incoming frequency. The electron stream issuing from the electron gun 125 is velocity varied at the gap 126 and impinges upon the secondary emitters 133 and 134 to excite at each of these emitters a laterally directed secondary electron emission which is density varied in accordance with the varying velocities of the incident primary electrons. The density varied secondary electron streams passing to the collecting anodes 139 are each caused to traverse one of the two portions of the primary winding of the output transformer 140 in push-pull fashion to transfer amplified electric wave energy to the output circuit 141.

What is claimed is:

1. The method which comprises producing an

electron stream, limiting the total electron flow at its source to a magnitude less than that which the electron impelling force would readily withdraw from the source, varying the electron impelling force to vary the velocity of the electrons emitted by the source and causing the varied velocity electrons to impinge upon a secondary electron emitter the response of which varies with impact velocity of impinging electrons.

2. In combination, an electron velocity variation device comprising a cathode, a secondary electron emitter, a source of electron impelling electromotive force connected between the cathode and secondary emitter and exceeding in magnitude the electromotive force required to withdraw all the electrons which the cathode is capable of emitting, and means for varying the electron impelling force to vary the velocity of the electrons emitted from the cathode whereby the number of electrons yielded by the secondary emitter varies in accordance with said varying impelling force.

3. In combination a primary cathode, a source of secondary electrons, an electron collecting anode, a source of electron impelling electromotive force connected between the primary cathode and the secondary electron source, a source of electromotive force exceeding that required to withdraw all of the electrons which the primary cathode is capable of emitting under normal temperature conditions, the source of secondary electrons lying in the path of electrons from the primary cathode, and means for varying the impelling force applied to electrons between the primary cathode and the secondary electron source in accordance with control forces to vary the impact velocity of primary electrons impinging upon the secondary electron source without substantially varying the number of primary electrons.

4. In combination an electron gun, means for variably accelerating the velocity of electrons emitted thereby, a secondary electron emitting target in the path of the electron stream emitted from the gun, a collecting anode for the secondary electrons, the secondary electron emitting target having such an inclination to the incident primary electron stream that the secondary electrons emitted pass in a beam in a direction diverging from that of the incident stream, and a shield between the collecting anode and the path of the incident primary electron stream to prevent the anode from affecting the incident stream.

5. An electron discharge device comprising a source of an electron stream of relatively constant density and constant electron velocity, means for varying the velocity of the electrons of the stream, a secondary electron emitter positioned in the path of the varied velocity electrons and having electron emission properties which depend upon the velocities of incident primary electrons, a collector for secondary electrons emitted by the secondary emitter and a conductive screen between the source of the constant density stream and the secondary emitter and collector to prevent the varying field of the secondary electrons from affecting the source of the constant density stream while permitting substantially free flow of the velocity varied stream to the secondary emitter.

6. In combination, two substantially closed resonant chambers separated by a conductive screen means for introducing electromagnetic

waves to be amplified within the first chamber, a source of an electron stream of substantially constant velocity and density also within the first chamber, means for subjecting the electron stream to the electromagnetic field within the first chamber to vary its electron velocity, means for impelling the velocity varied stream into the second chamber, an electron multiplier system position in the second chamber so as to be affected by the varied velocity electron stream and means for withdrawing from the second chamber amplified oscillations set up therein by the electron multiplier in consequence of the variations of electron velocity of the exciting electron stream.

7. An electron apparatus comprising an electron discharge device including an electron emitter, a secondary electron emitter and a collector for the secondary electrons, means for causing the electrons from the electron emitter to impinge upon the secondary electron emitter and for causing secondary electrons emitted by the secondary emitter to be collected by the collector, an input circuit external to the device connected between the electron emitter and the secondary electron emitter to vary the velocity of electrons incident upon the secondary emitter, and an output circuit external to the device connecting the electron emitter with the collector.

8. An electron discharge device comprising a source of an electron stream of relatively constant density and constant electron velocity, means for varying the velocity of the electrons of the stream, a secondary electron emitter positioned in the path of the varied velocity electrons and having electron emission properties which depend upon the velocities of incident primary electrons, a collector for secondary electrons emitted by the secondary emitter, a conductive screen between the source of the constant density stream and the secondary emitter and collector to prevent the varying field of the secondary electrons from affecting the source of the constant density stream while permitting substantially free flow of the velocity varied stream to the secondary emitter, and a suppressor grid positioned between the collector and the secondary emitter to prevent emission of electrons by the collector.

9. The method of energy transfer which comprises varying the velocities of electrons of an electron stream in periodic manner, bombarding a secondary electron emitter with the velocity modulated stream and deriving therefrom a stream of secondary electrons the density of which varies with the velocity of the impinging primary electrons.

10. The method which comprises producing an electron beam, varying the velocities of its electrons in accordance with a control force and causing the velocity varied beam to impinge upon a secondary emitter whereby a beam of secondary electrons varying in density with the control force is produced.

11. An electron emitter, an electron collector having the property of emitting secondary electrons upon impact thereon of a primary electron, and means for varying the velocities of the electrons from the emitter and directing the velocity varied electrons against the collector.

12. In combination in an electron discharge device, a cathode, an anode having a secondary electron emitting surface, means for causing electrons to be impelled from the cathode to the an-

ode to give rise to secondary electron emission therefrom, and means for superposing an additional acceleration upon the electrons in transit between the cathode and the anode to vary the velocities with which the electrons reach the anode.

13. In combination, a source of an electron beam, means for varying the velocities of the electrons of the beam as they pass a given zone, a target in the path of the beam adapted to emit secondary electrons whereby the number of secondary electrons emitted is a function of the velocities of the primary electrons which impinge upon the target, and means for collecting and utilizing the energy of the secondary electrons.

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