[Second Edition.]

PATENT SPECIFICATION

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Complete Accepted: March 8, 1929.

COMPLETE SPECIFICATION.

Improvements in Power Operated Vacuum Tube Construction and Circuit therefor.

We, ARCTURUS RADIO COMPANY, of 225, Sherman Avenue, Newark, State of New Jersey, United States of America, a corporation organised under the Laws of the State of Delaware, United States of America, (Assignees of WALTER LOUIS KRAHL, of 73, Orange Road, Montclair, New Jersey, United States of America, a citizen of the United States of America) do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to electron emitting devices of the general type known as thermionic vacuum tubes and to circuit arrangements therefor, and more especially to tubes of the type in which the cathode is heated by radiation transferred thereto from another source of energy.

More particularly, the invention relates to a thermionic tube so constructed as to permit the use of ordinary household or fluctuating lighting current as a power source for heating the cathode material of the tube to electron emitting temperatures, and to circuit arrangements which permit utilization of the tube in this manner at a high degree of efficiency.

One of the objects of the present invention is to provide a thermionic device, which is adapted to operate if desired, on an alternating or fluctuating current for cathode exciting purposes, and the output of which is independent of fluctuations in heater current, and particularly is free of "hum" heretofore usual in such devices when used on alternating currents of commercial frequency. Another object of the invention is to provide a device of the class described which is simple and economical to construct, and positive and reliable in operation.

Another object of the invention is to provide a vacuum tube of the four element type including plate, grid, cathode and heater with such connections as will permit its use in an ordinary or standard type of four terminal socket, the terminals of the tube being four in number and all positioned upon the base of the tube in the ordinary manner, and with all leads passing through the base and through a single press into the evacuated envelope, so that the insertion of a tube according to our invention into a standard four contact socket to which circuit connections are established, closes all necessary contacts.

A further object contemplated is the utilization of input and output circuits which when employed in conjunction with four element tubes of the type herein specified, function to eliminate hum from the output circuit when fluctuating current is applied to the tubes for cathode heating.

Still another object is the provision of a circuit arrangement which when employed with a radio receiving set, will permit optional use of said set without modification of internal wiring, either with alternating or fluctuating direct current tubes as disclosed in this application and in our Patent No. 278,750 on the one hand, or with standard constant direct or battery current tubes on the other hand.

Another object is the utilization of a tube construction in which the cathode is separated from the heater element, and insulated therefrom by vacuous space only. Further objects will become apparent on consideration of the following specification and accompanying drawings which are descriptive of an embodiment of the invention which may be preferred, and in which

Fig. 1 is an elevational section of a vacuum tube incorporating the novel base construction of the invention, and a portion of the circuit arrangements;

Fig. 2 is a wiring diagram illustrating the application of the tube in a simplified radio receiving circuit modified in accordance with our invention;

Fig. 3 is a diagrammatic showing of the tube circuits of the tube itself;

Fig. 4 is a wiring diagram illustrating the application of our invention to a multi-stage amplifying circuit utilizing more stages than the circuit shown in Fig. 2; and

Fig. 5 is a wiring diagram showing an

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arrangement of circuits to which either standard direct current tubes or the tubes in this application may be optionally used without altering internal wiring of the circuit.

The type of thermionic vacuum tube now in general use is provided with three internal elements, the anode, cathode and control electrode or grid, the cathode being in the form of a filament adapted to be heated by a dry or storage battery or other source of approximately constant potential unidirectional current. For this tube four base terminals are utilized, affording connection to grid and plate, and a series connection through the filament. This type of tube is in most cases unsuited for use in connection with a fluctuating or alternating current, commonly used for house lighting, because of the pronounced hum produced in the output circuit.

In the present invention, use is made of a four element tube operative on alternating current without substantial hum as described in our Patent No. 278,750, in which the cathode and heating element are physically separated, the heater being substantially enclosed by the cathode, but electrically connected in series therewith as regards heating current.

Heretofore, it has been the usual practice in four element tubes to keep the cathode physically and electrically separated from the heating filament which made it necessary to provide such a device with at least five external terminals, two for the heater circuit, one for the cathode, and one each for the plate and grid. In the present arrangement, however, we utilize only four terminals for these four elements, by including the cathode in the heating circuit in series. All of these terminals are positioned in the tube base in the usual relationship so that the ordinary commercial type of vacuum tube socket is adaptable for the use of the tube, and the insertion of the tube therein completes all necessary connections.

In accordance with our invention, we have illustrated an embodiment of the vacuum tube construction in Fig. 1, in which the envelope 10 is preferably formed of glass or similar material in the usual elongated tubular shape with a base 11 attached thereto, this base being adapted for insertion in the ordinary type of socket, and for this purpose having four terminals 12, 13, 14 and 15 extending from the end. The envelope 10 is optionally covered with a metallic deposition forming a film 16 which may extend partially or wholly about either the exterior or interior surface, although we have herein shown the exterior surface as so covered as that is the preferred construction.

Within the tube there are provided among others, certain of the usual elements necessary for the amplification or rectification of radio signals, including the anode which may be in the form of a cylindrical plate 17, the control electrode in the form of a grid 18, and the cathode 19. The cathode may be of the type described in our Patent No. 278,750, as for example a tube of nickel or other suitable metal having a coating 20 of a substance or mixture such as oxides of barium or strontium possessing high electron emitting properties when heated. The limits of the cathode coating terminate well within the plane fixed by the plate ends. Also in some instances, we may slit the tube axially to diminish inductive reactions arising from the heater element.

Where this is done it is preferable that the shielding of the heater be maintained undisturbed; and this may be accomplished by omitting that portion of the grid structure adjacent the cathode slot or by forming the cathode in a spiral sheet corresponding to the spirally wound grid.

The heater for the cathode is separate therefrom and consists of the filament 21, preferably but not necessarily carbon, extending co-axially within the cathode and connected to the cathode at one end, preferably the end remote from the press, through the spring arm 27, support rod 28, and conductor 29, so that both cathode and filament are in series when heating current is supplied as contemplated. The function of the spring 27 is to permit adjustment of the heater in accordance with temperature variation. The cathode tube 19 encloses the heater filament 21 and extends preferably above and below the same, so as to form an effective shield for the heater and to diminish hum arising from difference in potential between heater and other tube elements. Preferably the cathode tube should enclose the heater filament from the point adjacent the junction 7 of cathode and filament to the tube stem support at 9, and for this purpose we have illustrated the sleeve 8 as an extension of the cathode tube and resting on the stem and in electrical contact with the cathode tube 19 completing a shield which encloses that part of the alternating current supply within the vacuous space which has a potential value different from that of the cathode. The sleeve 8 is axially slit to facilitate assembly, the slit being disposed away from the grid lead so that a solid shield is interposed between the grid lead and alternating current lead having a potential different from that of the cathode.

The cathode and heater are separated by vacuous space rather than by a solid dielectric primarily to facilitate manufacture of tubes as a mass of solid material within the space to be evacuated would greatly increase the difficulties of proper evacuation, and secondarily to avoid time lag in reaching temperature equilibrium in operation due to the mass of the solid dielectric. The electrical connection of cathode and heater at a common point in conjunction with the spacing apart of these elements and separation only by vacuous space and the use of carbon and the use of circuits hereinafter described, permit the use of relatively high potentials and low current values within the tubes, which may be as high as sixteen volts, and as low as twenty-five hundredths ampere. As electro-magnetic disturbances are usually more troublesome than electro-static disturbances when alternating currents are used for cathode heating, since electro-static disturbances are easily cared for by thin metal shielding, we prefer to employ a low current preferably not exceeding five tenths amperes and high voltage, and the advantages which we have been able to obtain are apparent in the freedom from disturbing noise and " hum " even in multistage amplifiers.

Note should be made further of the advantageous use of carbon as a heater element for the cathode. The use of a single straight stiff filament of high resistance such as carbon and of short length and small linear expansion positioned concentrically within the cylindrical cathode, permits close positioning of the cylindrical cathode even without a solid dielectric, thereby decreasing the area of cathode in direct proportion to the diameter as will be understood. If we assume a constant amount of energy transfer from the heater per unit of area of the cathode to maintain said unit area of the cathode at electron emitting temperature then since the cathode area is decreased proportionally as the diameter is decreased, the energy required is also decreased and the current supplied to the filament may be reduced as the square of the cathode diameter, thereby reducing the magnetic fields which tend to cause hum. It will be seen, therefore, that a close fit of the cathode around the heater made possible by the use of single short straight high resistance carbon filament concentric with the cathode sleeve and separated only by a vacuous space, makes possible the reduction of heater current and magnetic field to a point where disturbing noise and hum is substantially eliminated even for many tubes in cascade. Also at the relatively low temperature of operation, averaging below white heat, the heating element has exceptionally long life. Where carbon is used as the material of the heater, we preferably make use of copper as an intermediary welding element between the carbon filament and its support. The use of carbon as well as copper is found to be advantageous, moreover, as these materials function as getters in the tube exhausting process, absorbing or occluding the gas residue in the tube after sealing.

The cathode being in tubular form has a considerably larger effective emitting surface than filamentary cathodes and hence has ample electron emitting capacity for all ordinary uses including operation as a so-called " power tube ".

The plate, grid, cathode and heater filament are each supported upon the single tube stem 22 by means of appropriate connections and standards as clearly shown in Fig. 1, the glass bead 6 being necessary as a support for the grid and plate.

The base 11 is preferably but not necessarily formed of insulating material and is provided at its end with the four terminals 12, 13, 14 and 15, hereinabove referred to. Connections from the tube elements to the base terminals are made as follows: from the plate 17 by wire connection 23 to the terminal 15; from the grid 18 by wire 24 to terminal 14; from the heater filament 21 to the terminal 12 by wire 25; from the cathode 20 to terminal 13 by wire 26; and from the other end of the cathode 20 and heating element 21 to the terminal 13 by means of the support rod 28 and wire 26^1. Connection is also made from the external surface film 16 to the terminal 13 by means of wire 27 for the purpose of grounding the metallic film on the envelope.

With the above connections it is apparent that we have provided a four element vacuum tube adapted to be heated by alternating current, and all of the connections for which are in the base of the tube, and having the standard spacing and disposition so that the mere act of inserting the tube in a standard socket makes all the necessary connections, there being only four required terminals for the operation thereof. As brought out in our Patent No. 278,750, the use of alternating or variable current as a power source is made possible by utilizing in the tube, heating means for the cathode physically distinct from and electrically shielded by the cathode, and by providing a common connection between cathode and heater filament, so that the cathode functions primarily as an electron emitting body without appreciable effect on the grid and plate arising from potential variation

introduced by the heating current.

In Fig. 2 of the drawing we have illustrated a circuit particularly adapted for the reception of radio signals by means of a tube according to our invention. Only three tubes are shown as employed in this arrangement illustrating by way of example one stage of radio frequency amplification including tube I, a rectifying or detecting circuit utilizing tube II and an audio amplifying circuit or stage employing tube III. There is illustrated the signal receiving circuit or antenna 30, connected through primary winding of transformer 31 to ground, the secondary winding of which transformer is connected to tuning condenser 32. The voltage developed thereon is impressed upon the input circuit of tube I between the grid or control electrode 18, and the heater-cathode circuit comprising heater filament 21 and the cathode tube 19, at a point which is not separated from the cathode by any appreciable resistance in the path of the heating current, which resistance might produce a hum due to the voltage drop through it.

Since the filament resistance is high and the cathode tube resistance relatively low, it suffices to connect the grid return to any point on the cathode tube 19, or to the end of the heater filament 21 which is connected to cathode tube 19. This metallic low resistance connection of the grid return to the cathode heater circuit fixes the potential between grid and cathode for low frequencies so that for any fluctuations of cathode potential due to heating current, the grid fluctuates similarly and no potential difference appears between cathode and grid; thus preventing or minimizing the possibility of noise being introduced by the voltage drop through the heater affecting the grid-cathode potential through unbalanced capacity effects, as might occur if the cathode were electrically isolated from the heating circuit.

The output from tube I is passed through the primary and secondary of transformer 34, to detector tube II in the detector or rectifying circuit. This circuit includes also a condenser 33, grid condenser 36, grid leak 37 and by-pass condenser 38. The output of detector tube II is passed through transformer 35 into amplifying tube III and the output of tube III is utilized to energize a suitable sound amplifier 39.

The heat energy for the cathode is provided from the alternating potential source illustrated at 42, operating through the transformer 43, including the primary 44 and secondary 45. One end of the secondary is connected to the left hand or negative filament binding post 46 of each socket by appropriate connection. Similarly the positive or right hand terminals 47 of the base of the various tubes connected together are joined to the other terminal of the secondary. Also the grid returns of tubes I and III are connected together by conductor 48.

For volume control we have provided rheostats 90 and 91, the rheostat 90 being positioned in the secondary circuit of the power transformer 43 and the rheostat 91 in the plate circuit of the detector tube II of Fig. 2 or III of Fig. 4.

Auxiliary potential and power sources are utilized in the B-battery 40 connected to the various tube anodes; in the C-battery 41 in the grid circuit of the audio amplification stage as usual in the art. The battery 49 which we term a D-battery, applied between the grid return 48 and the heater cathode connection 47, however, forms a part of our invention, as does the battery 50 which we term the E-battery which may be connected to the surface films 16 of the various tubes.

The B and C batteries have in the circuit their usual functions of providing respectively a positive plate potential in all tubes and a negative grid bias in the last or audio stage. The D-battery has the function of preventing diminution of signal output or distortion resulting from phenomena within the tubes, and the E-battery functions to impart a negative bias to the tube films 16, which are shown as connected to the cathode leads. Also we may connect the tube films 16 directly to the low potential or cathode circuit. In either case, with or without E-batteries, the tube films serve to overcome capacity or electro-magnetic disturbances arising, it is believed from the conductors, both without and within the tube.

While reference is made to the B, C, D and E batteries it is not intended to limit the invention to the use of batteries, as optionally connections may be made to any source, such as to taps on an eliminator.

In Fig. 5 we have illustrated a wiring arrangement in which there is provision for alternate connection to either direct or alternating current power sources for tube cathode heating. With this circuit installed in a radio receiving set, for example, it is possible to utilize ordinary alternating or fluctuating house lighting current in conjunction with my four element tubes or optionally a dry or storage A battery may be connected to the set in conjunction with three element tubes employing the usual filament-cathode.

Figs. 4 and 5 also illustrate use of cascade amplification in which we employ

two stages of radio frequency amplification in conjunction with a rectifier or detector stage.

Since the noise as well as the signal produced by each tube is amplified by all the successive tubes, it will be seen that our tube and circuit arrangements are highly effective in eliminating noise and hum, as five, six or even more tubes may be arranged in cascade without the production of appreciable or disturbing noise or hum effects.

Referring to Fig. 4 in addition to the added stages, we have shown a modified connection of the grid return of the detector tube III to the common conductor 48 instead of the conductor 47. Also with this variation we have connected the grid leak 37 to the cathode lead of the tube III.

In addition, this circuit has provision for connection of an A potential at 70 for example, and switches 71 and 72 to cut out the alternating current source and substitute the direct current which may be derived from dry or storage A batteries or from any other power source. The four usual tube base terminal contacts 73, 74, 75 and 76 are indicated to which connection to the grid, plate and plus and minus filament terminals of a three element tube may be made as well as to the four elements of our alternating current tube.

In Fig. 5 is clearly illustrated the circuit arrangement and mode of connection to either an alternating or direct power source, the dotted line 77 indicating alternating, pulsating, or fluctuating current conductors, the broken line 78 indicating direct current conductors, and the full line 79 indicating conductors usable by either direct or alternating currents.

In this arrangement all conductors adapted to carry alternating or fluctuating current at potential values differing from that of the cathodes, should be shielded or spaced from other portions of the circuit, including the alternating current conductors common to the cathode so that inductive or electro-static coupling is ineffective. Also all inductances such as inductive filament control rheostats in alternating current conductors should not be located in effective proximity to the wiring of the receiving apparatus.

In the diagram as shown in Fig. 4, the grid returns of all the tubes are connected to a common lead 80 from which connection may be made either to the tube cathodes for alternating current or to the low potential side of an A-battery as in direct current usage. Also alternatively the grid returns of each tube may be connected directly to the cathode of the corresponding tube in alternating current usage.

We may also optionally use a D-battery in either alternate type of circuit, that is, where the grid returns of all tubes are connected together and then through a common D-battery to the tube cathodes or where the grid returns of each tube are directly connected to the tube cathode through a D-battery. Also the value of the D-battery may be varied in accordance with tube requirement and it is within the province of our invention to eliminate the D-battery entirely whenever the tube characteristics are such as to permit such elimination.

In the construction of the thermionic tube of our invention, it is of course understood that the exact dimensions of parts may be varied within limits in accordance with the uses to be made of the tube. As illustrative, however, of a precise tube construction which has been found advantageous, the following values are given: diameter of heater filament 0.005 inches, length of heater 1—1/8 inch, diameter of cathode 0.095 inch, length of cathode 1—1/4 inch, length of oxide coating 11/16 inch, diameter of grid envelope 3/16 inch, length of grid envelope 3/4 inch, diameter of plate tube 5/16 inch, length of plate tube 3/4 inch. The cathode tube has a wall thickness of approximately 0.0025 inch.

The voltage of commercial current used in connection with my tube is assumed to be approximately 110 although any ordinary value will give satisfactory results. The transformer 45 has preferably such constants as will produce a voltage ranging around 16 in the secondary 45.

It is to be understood that the tubes herein described are also applicable to fluctuating direct current for cathode heating. When application is made to direct current a resistance inserted in series with the filaments of the tubes is used to reduce the voltage to proper value.

Various modifications of the base connections and of wiring of the circuit may be made in accordance with specific requirements in application of the invention, and hence we desire to include all of such modifications and alterations within the scope of the claims hereto appended.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. In a thermionic system, a thermionic relay comprising an electron emitting cathode of relatively low resistance; a

heating element for said cathode in the form of a single straight element; said cathode and heating element being electrically connected together and separated from each other throughout the energizable length of said heating by space entirely free from solid matter; an anode; a control electrode; an output circuit connected between said anode and said cathode; and an input circuit connected between said control electrode and said heater element at a point having substantially cathode potential.

2. In a thermionic system, the combination as set forth in claim 1, characterised by the fact that the thermionic relay is mounted on a base having four electrical terminals connected to said anode; control electrode, cathode and heater, said terminals being arranged according to standard practice, and a socket having four contacts arranged according to standard practice, whereby insertion of the tube in the socket completes all connections to the anode, control electrode, cathode and heater terminals of the tube.

3. A thermionic system as set forth in claim 2, characterised by the fact that a common lead is connected to the cathode and one side of the heater which must therefore include a portion of the grid circuit, and the common lead having a resistance of such a value that the voltage drop in the said portion of the grid circuit is insufficient to produce an objectionable hum in the plate circuit.

4. The method of operating a thermionic relay as above claimed, characterised by the fact that the heating current does not exceed five-tenths of an ampere.

5. In a thermionic system, a plurality of thermionic relays arranged in cascade to pass electrical oscillations to be amplified through each of said relays successively, one of said relays acting as a detector, each of the relays being formed as above claimed and comprising an electron emitting cathode of relatively low resistance; a heating element for said cathode, said heating element and the cathode being electrically connected together and the heater and cathode of each of the relays being connected in parallel with the others; an anode; a control electrode; an output circuit associated with each of said relays and connected between the anode and cathode thereof; an input circuit for each of said relays connected to the control electrode; and a common return circuit for said input circuits connected to the heater filament circuit at a point having substantially detector cathode potential.

Dated this 8th day of October, 1927.

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Agents for the Applicants.

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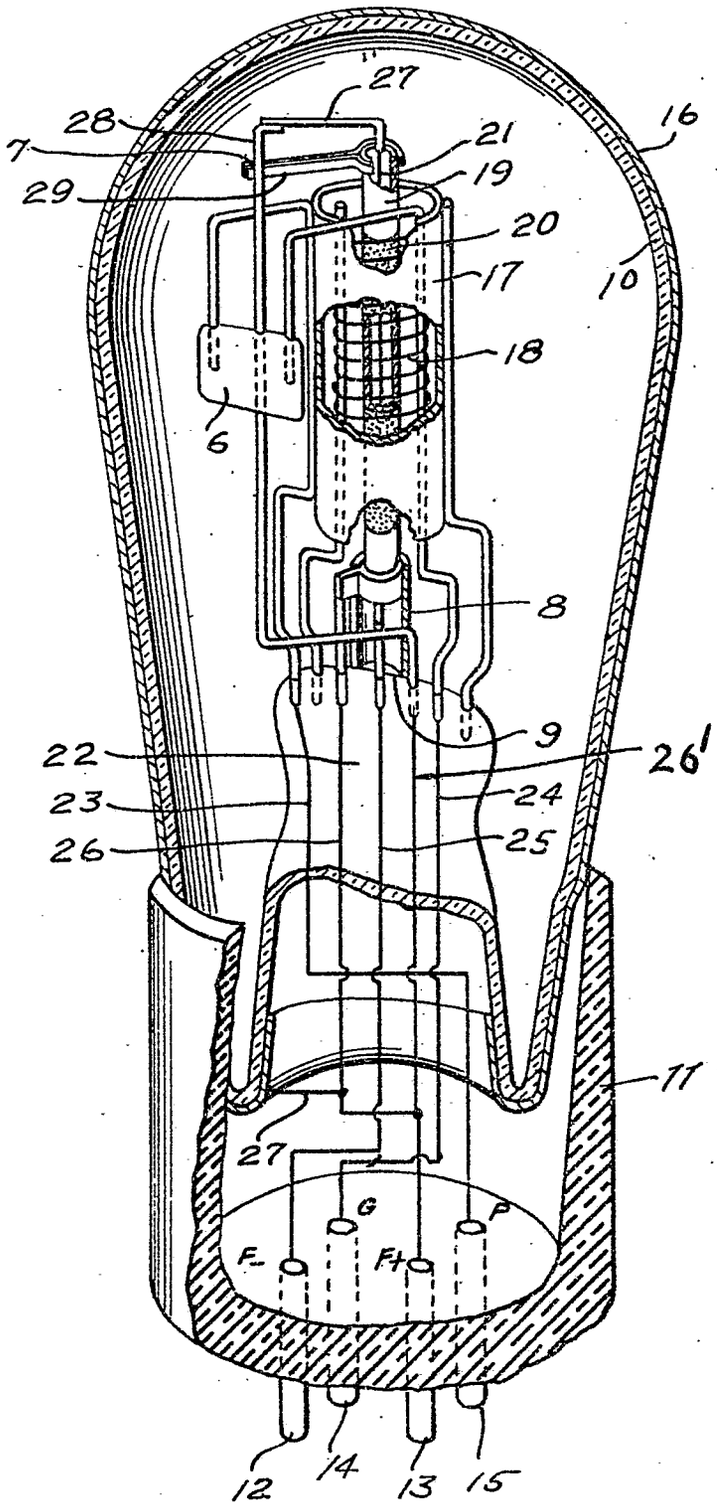
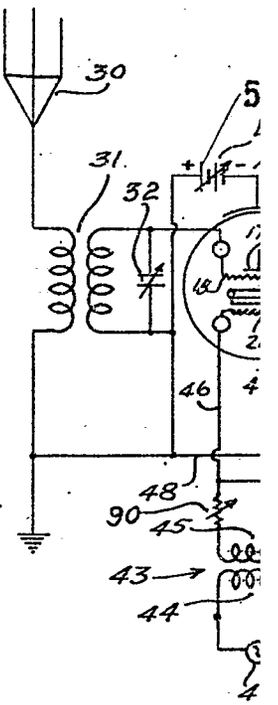
SHEET 1

Fig. 1





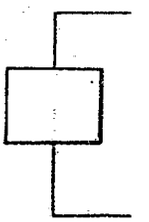


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Fig 2

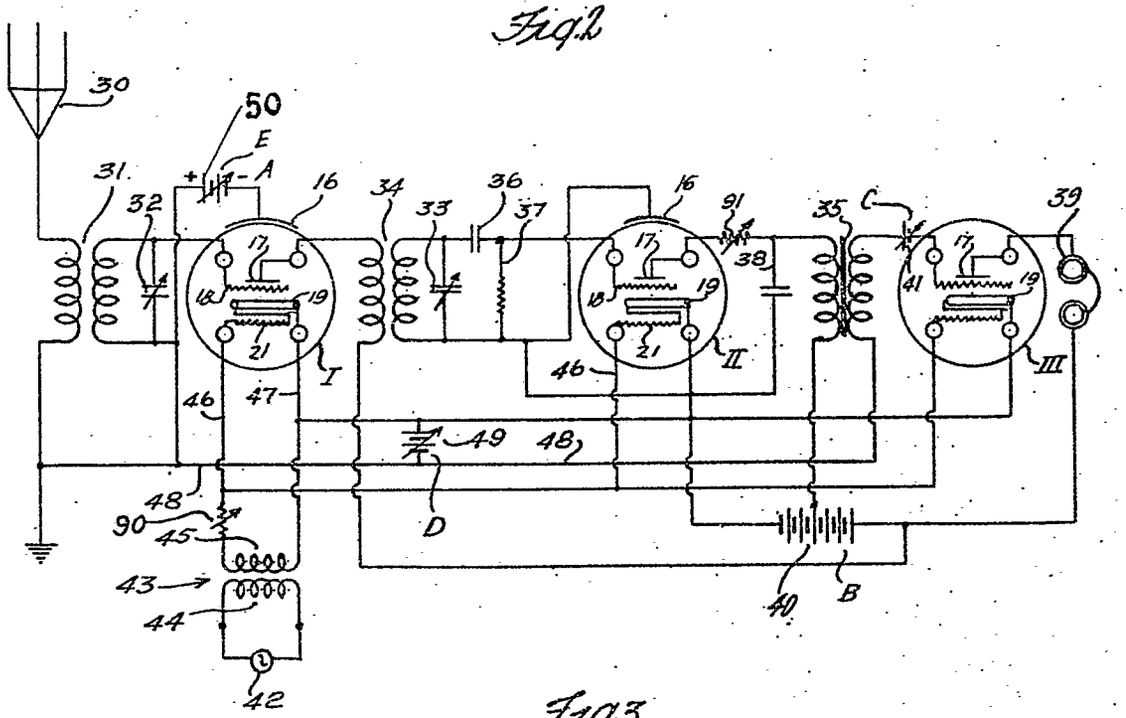
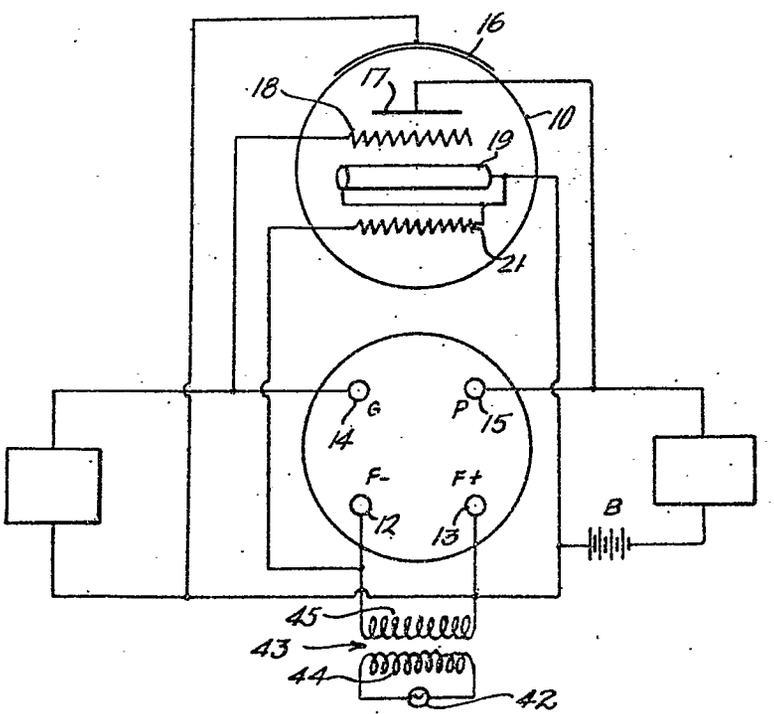


Fig 3



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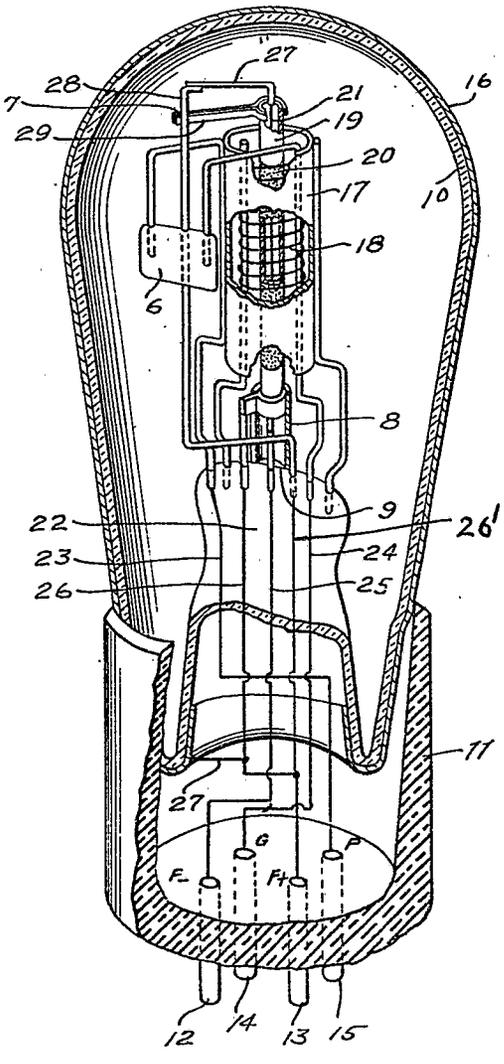
3 SHEETS

SHEET 1

Fig. 1



SHEET 2

Fig. 2

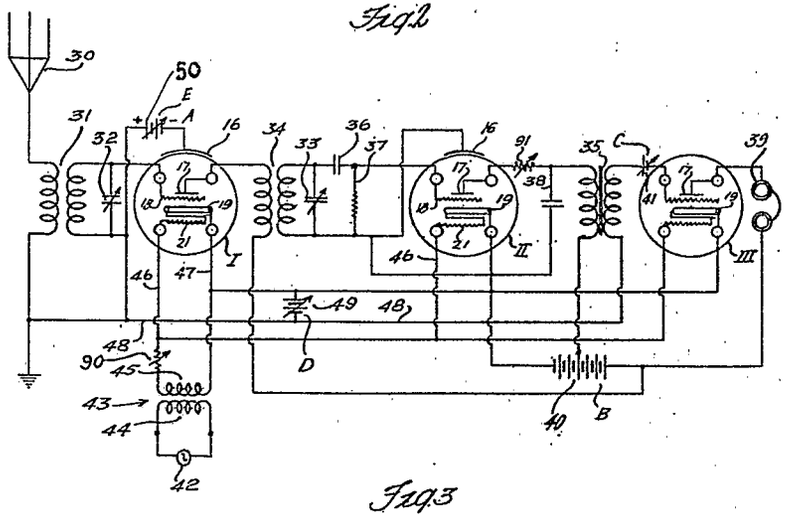


Fig. 3

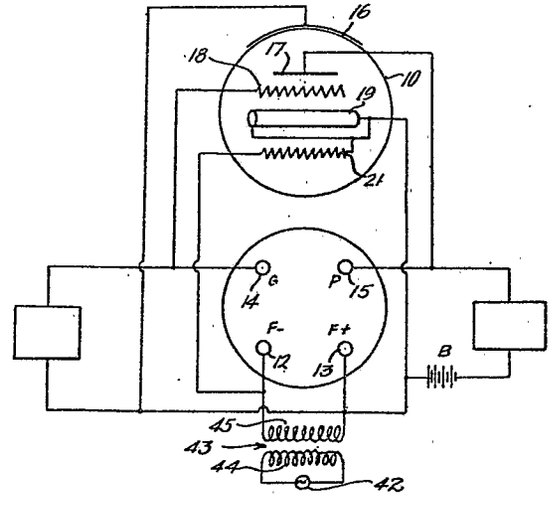


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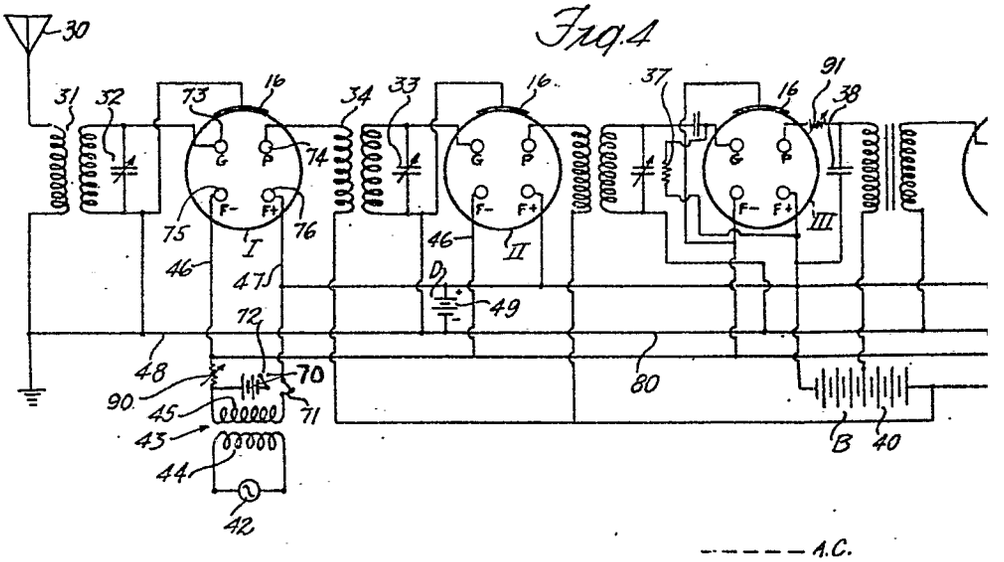
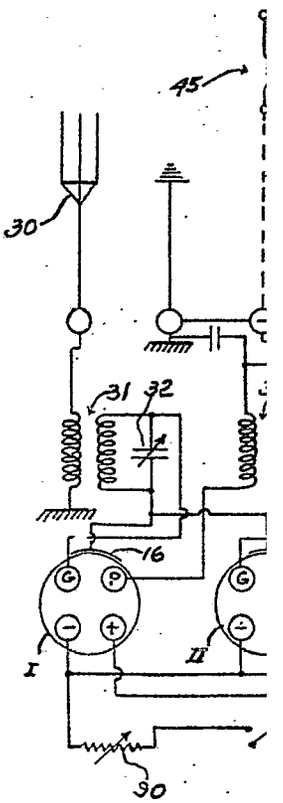
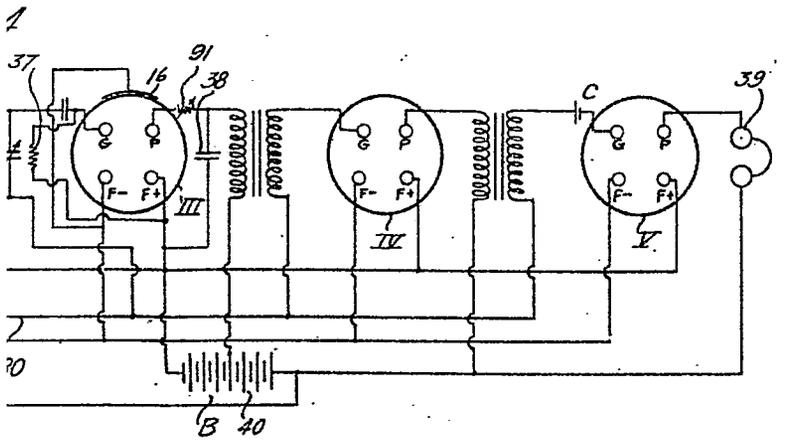
Fig. 4







A.C.
D.C.
A.C. OR D.C.

Fig. 5.

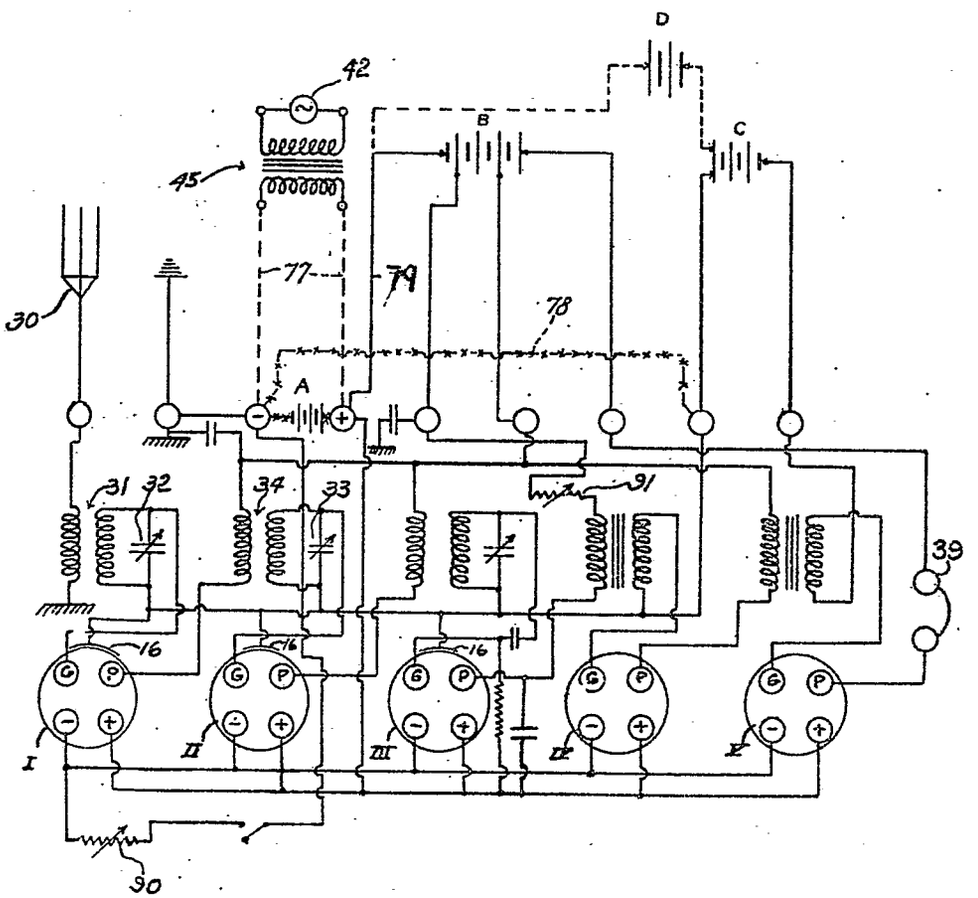


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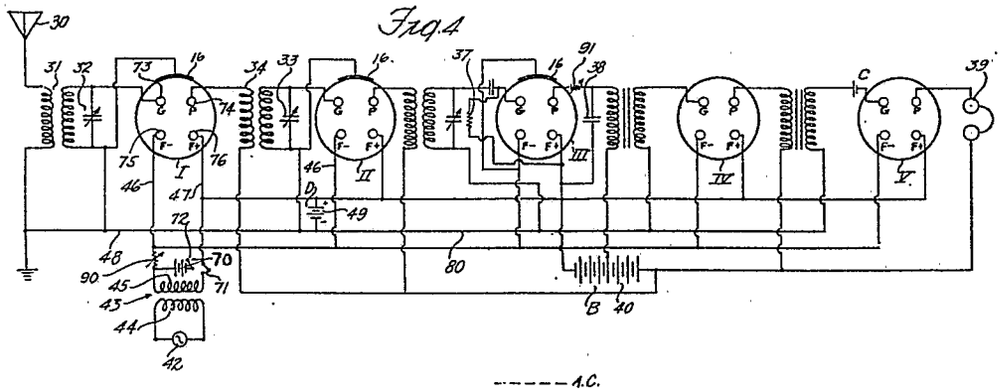
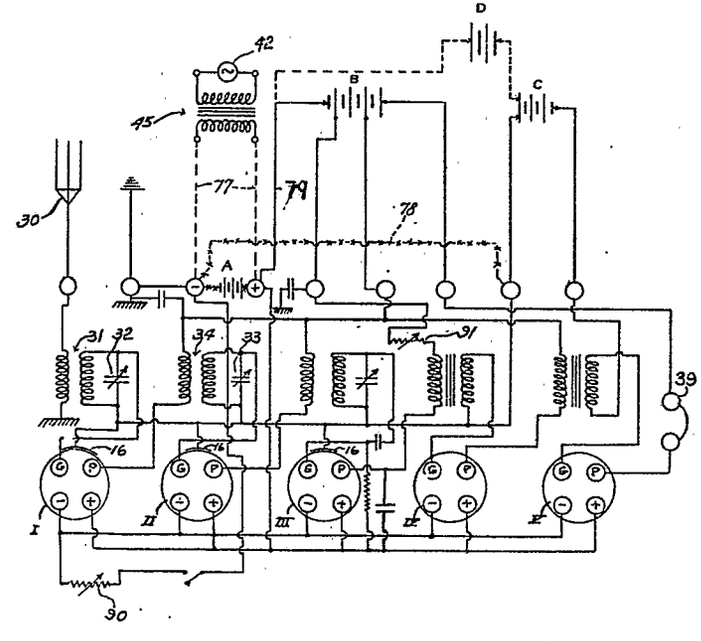
Fig. 4



A.C.
D.C
A.C. OR D.C.

Fig. 5.



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