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W. A. MARRISON

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ELECTRIC CONTROL DEVICE

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Fig. 1.

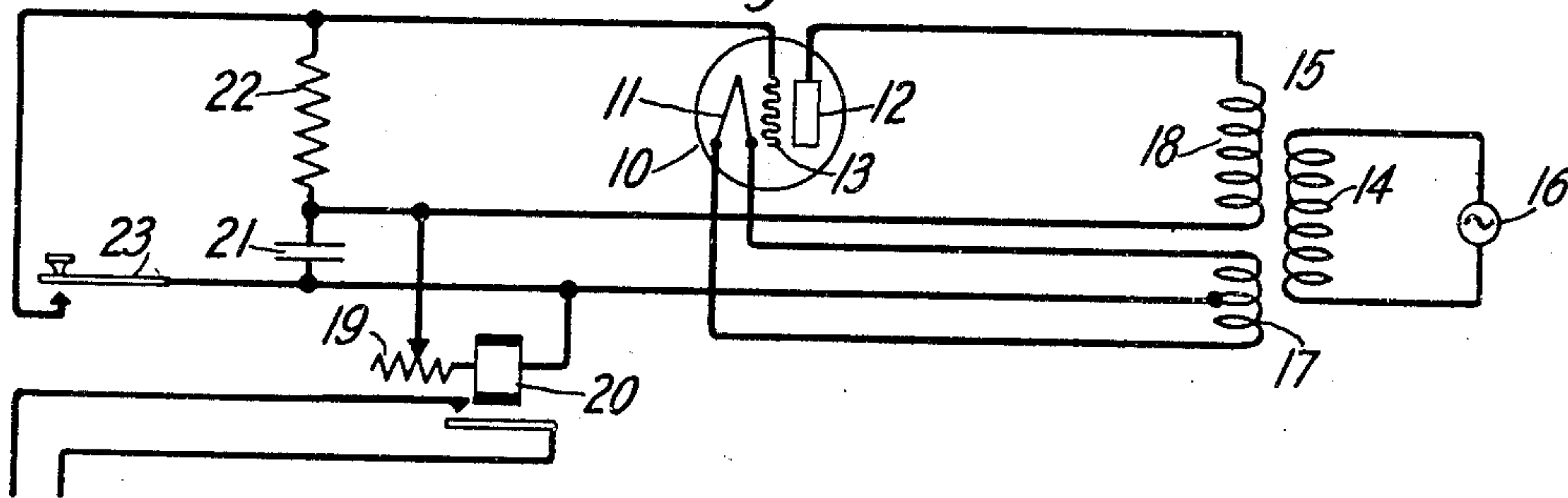


Fig. 2.

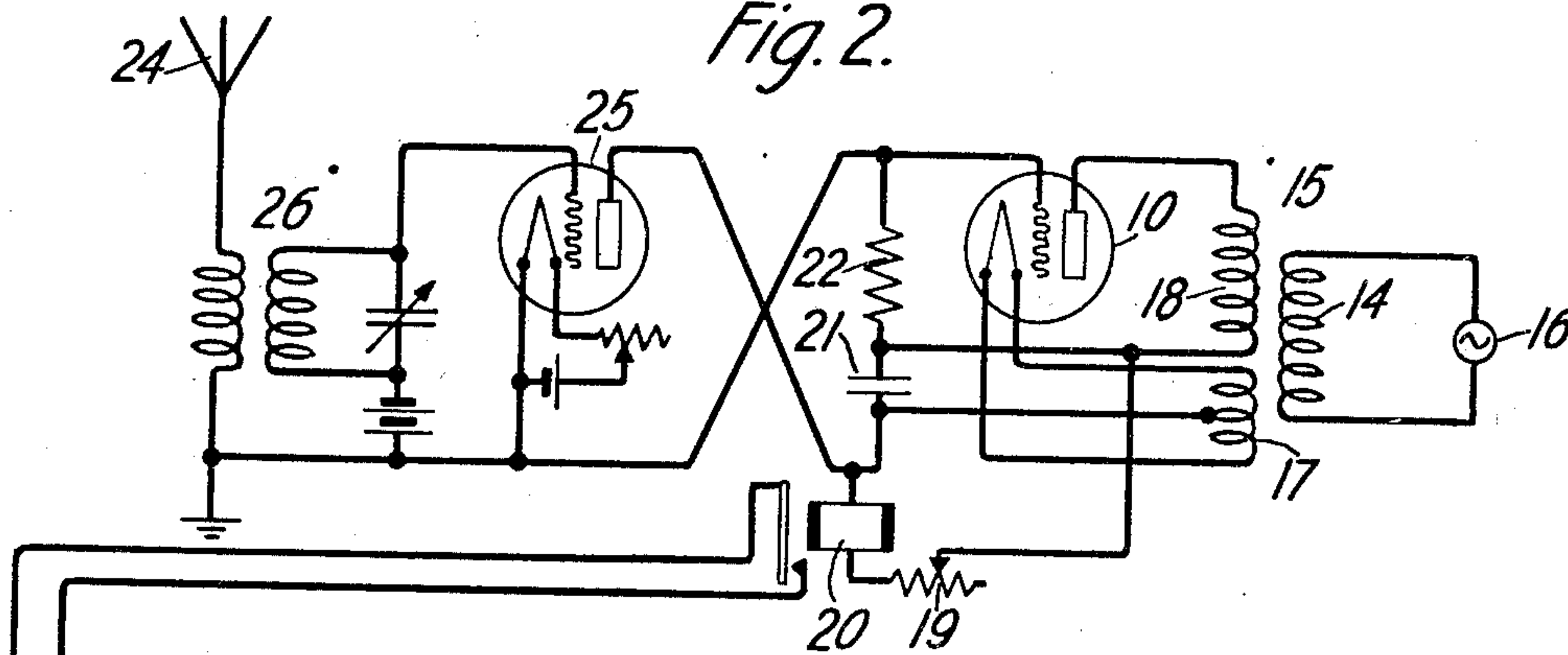
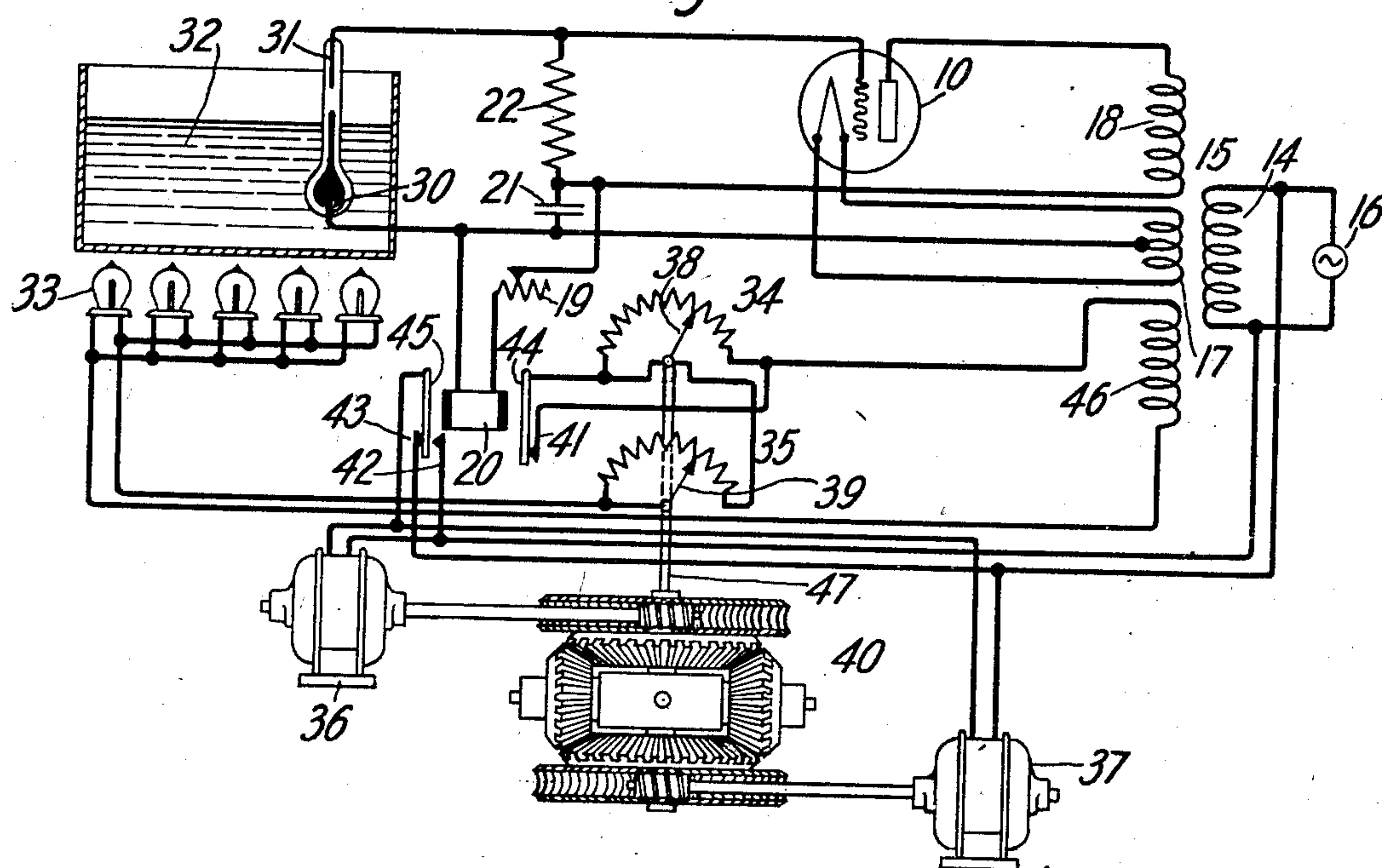


Fig. 3.



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UNITED STATES PATENT OFFICE

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ELECTRIC CONTROL DEVICE

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This invention relates to electrical control circuits and has for an object to control the operation of a circuit by the use of extremely small currents.

Another object of the invention is to energize an electrical control circuit from a single source of alternating current.

The invention, while not limited in this respect, is particularly applicable to temperature control systems in which a device for increasing or decreasing the current through an electrical heater is operated by the opening or closing of an electrical circuit through a temperature responsive device such as a mercury column and its associated electrode. In order to prevent sparking between the mercury column and the electrode, which would cause the deterioration of the contact and reduce the accuracy of its operation, it is desirable that the current carried by the circuit through the mercury column and the inductance of the circuit be made small.

In accordance with a feature of this invention, a relay is operated by the space current of a three-electrode electric discharge device; an impedance, which may be a winding of the relay, is connected to the device in such a way that the voltage drop across its terminals produced by the space current flowing therein is impressed between the control electrode and the cathode; and the operation of the relay is controlled by a variable impedance connection from the control electrode to the cathode, by means of which the biasing potential is changed.

This invention not only provides an arrangement in which the operation of the relay may be controlled through a circuit which carries a very small current but also one which is readily adaptable to be energized from a single source of alternating current. Thus, the cathode of the discharge device may be supplied with heating current from one winding of an alternating current transformer while space current is supplied from another winding, the discharge device functioning as its own rectifier and the operating current for the relay being obtained from the plate circuit of the discharge device.

In one specific embodiment of the inven-

tion, the control circuit is employed for regulating an electrical heater, the thermostat being required to carry only a minute current limited by a high resistance connected in the grid circuit of the discharge device, and the control circuit and electrical heater both receiving current from a single source of alternating current.

In another specific embodiment of the invention, the variable impedance connection for controlling the biasing potential comprises a second electric discharge device, the impedance of which is controlled by means of electromagnetic waves received from a distant radio transmitting station.

Obviously, the feature of the latter embodiment, namely that of operating the control circuit through the use of a second discharge device, may be employed in any case in which it is desired to operate the control circuit from an electrical source of low energy level.

The following is a description of the invention in its several aspects so that it may be readily understood by those skilled in the art.

Fig. 1 is a diagrammatic showing of the electric control device of the invention.

Fig. 2 is a diagrammatic showing of the control device applied to a receiver of electromagnetic waves, and

Fig. 3 is a diagrammatic showing of the control device applied to a thermostat.

The control circuit shown in Fig. 1 employs a vacuum tube 10 having a cathode 11, anode 12 and grid 13. The primary winding 14 of transformer 15 is connected to a source of alternating current 16 and the secondary winding 17 is connected to the cathode 11 of the vacuum tube. One terminal of another secondary winding 18 is connected to the anode 12 while the other terminal of this winding is connected through a variable resistance 19 and the operating winding of a relay 20 to the mid-point of secondary winding 17. A condenser 21 of large capacity is connected between the mid-point of the transformer winding 17 and the terminal of the transformer winding 18 which is connected to the resistance 19. This terminal of winding 18 is also connected to one terminal of a resistance 22, preferably of several megohms, the other ter-

minal of this resistance being connected to the grid 13. The poles of switch 23 are connected to the grid 13 and the mid-point of the transformer winding 17, respectively.

In operation, the alternating potential supplied through transformer winding 18 to the anode 12 of the vacuum tube 10, causes rectified current to flow in a positive direction from the cathode 11 through transformer winding 17, the winding of relay 20, resistance 19, transformer 18, thence back to the anode 12. The condenser 21 serves to shunt out a large portion of the alternating current component of the rectified current flowing in the anode circuit. The potential drop across the resistance 19 and the relay winding 20 is impressed upon the grid 13 through the resistance 22 for supplying a negative bias to the grid, thereby limiting the current flowing in the anode circuit and through the winding of relay 20. The current through this relay winding is adjusted by means of the resistance 19 to such a value that it is normally insufficient to cause the operation of the relay. When the switch 23 is closed, however, a low resistance connection is provided between the grid 13 and the cathode 11 of tube 10 thus changing the grid biasing potential from a negative value to practically zero. Due to this change in grid bias, the current flowing through the anode circuit is increased to a value sufficient to cause the operation of relay 20. By employing a resistance 22 of large value the current flowing through the contacts of switch 23 may be exceedingly small, for example, as low as a few micro-amperes, and since the impedance of the circuit through which this current flows has only a negligible reactance component, practically no sparking or heating occurs at the switch contacts. The fact that the value of resistance 22 is high also prevents the relay winding 20 from being short circuited by closing switch 23.

The control device shown in Fig. 1 may be adapted to numerous practical applications by substituting other variable impedance connections for the switch 23. In Fig. 2 the input circuit of the device is shown connected to the anode circuit of a vacuum tube detector 25 and is adapted to be operated by electromagnetic waves which reach the antenna 24 and are transmitted to the grid of the detector tube through the tuned circuit 26. The other circuit elements are the same as those in Fig. 1.

As is well known, the current flowing in the anode circuit and the resistance measured between the anode and cathode of a vacuum tube vary with the potential difference between the control electrode and the cathode. When, for instance, the grid is biased by a negative potential of sufficient magnitude with respect to the cathode, the anode current I_p , for a given value of anode potential, may be reduced to practically zero or a low value which we

may designate as I_{p1} . If an alternating potential having a peak voltage approximately equal to the grid biasing potential is now impressed upon the grid circuit, the anode current I_p will vary in accordance with the frequency of the alternating potential from zero to a value of I_p which we may designate as I_{ph} . The values of the direct current resistance r_p , measured between the anode and cathode of the tube corresponding to the values of I_{p1} and I_{ph} , respectively, may be designated as r_{ph} and r_{p1} , representing high and low values of resistance, respectively. The variations in r_p , corresponding to changes in I_p from 0 to I_{ph} , will be from infinity to some finite value of several thousand ohms.

The effect of impressing the alternating potential upon the grid of the detector tube 25, suitably biased as indicated above, is to change its anode resistance from a value r_{ph} to a value which changes in accordance with the frequency of the impressed voltage from r_{ph} to r_{p1} . The value of r_{p1} is sufficiently low that the magnitude of the negative grid bias of the vacuum tube 10 is considerably reduced for half the time that the alternating voltage is impressed on the grid of the detector tube 25, thus increasing the R. M. S. value of the anode current in tube 10. Since the relay 20 is unable to respond to the rapid change in current due to variations of the grid bias of the vacuum tube 10, it remains in the operated position during the whole period that the alternating potential is applied to the grid of vacuum tube 25.

In Fig. 3 the control circuit is shown applied to a thermostat for controlling an electric heater. The control circuit proper is the same as that of Fig. 1. The arrangement employed to vary the cathode potential applied to the grid of vacuum tube 10, consists of a mercury thermometer having an electrode 30 in contact with the mercury in the bulb of the thermometer and an electrode 31 with which the mercury column makes contact when the temperature is sufficiently high. The thermometer is immersed in a bath 32 the temperature of which is to be controlled and which may be heated by the electric heater 33. The contacts of relay 20, in the anode circuit of vacuum tube 10, serve to short-circuit the rheostat 34 and to operate either of the motors 36 or 37, these motors serving to simultaneously revolve the contact arms 38 and 39 of rheostats 34 and 35 through the differential gear 40.

In operation, when the temperature of the bath 32 is sufficiently high to bring the mercury column in contact with electrode 31, the grid bias of vacuum tube 10 is changed from a negative potential to practically the potential of the cathode. The anode current is consequently increased sufficiently to cause the operation of relay 20 thus opening the connection between armature 45 and contact 13

43 and closing the connection between armature 45 and contact 42. At the same time the connection between armature 44 and contact 41 is opened. For this condition the heating circuit may be traced from the upper terminal of transformer winding 46 through the resistance of rheostat 34, contact arm 38 of this rheostat, the resistance of rheostat 35, contact arm 39 of this rheostat, heater 33 and thence to the lower terminal of the winding 46. Starting from the upper terminal of the power source 16, a circuit may be traced through motor 37, armature 45 of relay 20, contact 42 back to the lower terminal of the power source 16, the motor 36 being short-circuited through armature 45 and contact 42 of relay 20. When motor 37 is in operation the arms 38 and 39 of rheostats 34 and 35 respectively, are revolved in a counter-clockwise direction, thus increasing the resistance in series with heater 33 and reducing the current therethrough. This operation is continuous until the temperature of bath 32 decreases sufficiently to break the contact between the mercury column and the electrode 31, thus restoring the negative bias to the grid of vacuum tube 10 and causing the armatures 44 and 45 of relay 20 to be restored to the position shown in the figure. As a result, rheostat 34 and motor 37 are short-circuited and a motor 36 is operated thus causing the clockwise rotation of the arms 38 and 39 of rheostats 34 and 35, respectively, and reducing the effective resistance in the heating circuit. A graph of the heating current plotted against time would show a slowly decreasing current followed by an abrupt increase, then a slowly increasing current followed by an abrupt decrease. When the system is in equilibrium the periods of increasing and decreasing current are approximately equal. When not in equilibrium, however, one of these periods is longer than the other so that the system is gradually brought to the equilibrium condition.

One of the advantages of this type of control is that the resistance 22 may have a sufficiently high value, several megohms for example, so that the current flowing in the circuit connected to the input of the control device is very small, for example, several microamperes. This together with the fact that the input circuit is practically non-inductive, substantially eliminates sparking at the contact points in the shunt circuit. The useful life and accuracy of a circuit closing means such as a mercury contact shown in Fig. 3 is, as a result considerably increased. A second advantage is that the control device does not require the opening and closing of a circuit for its operation but functions satisfactorily by employing across its input a shunt circuit of variable resistance such as the anode circuit of a vacuum tube employed as a detector of electromagnetic waves. The

device is operable, moreover, from a single source of alternating current power of any frequency.

What is claimed is:

1. In combination, an electric discharge device having a cathode, an anode, and an impedance control element, a source of alternating current for supplying space current to said device, an impedance element permanently connected in series with said alternating current source in the space current circuit of said device, connections from said impedance element to said control element including a resistance for impressing a biasing potential thereon, and means for at times directly connecting said grid to said cathode independent of said resistance for controlling the space current of said device.

2. A combination according to the next preceding claim in which said impedance element comprises the winding of a relay to be operated by the space current of the discharge device.

3. An electric control system comprising an electric discharge device having a cathode, a grid and an anode, input and output circuits therefor, a heat supply controlling device in said output circuit operable upon variation in the anode current, means for normally maintaining a potential difference between the grid and the cathode, temperature responsive means in said input circuit for varying said potential difference, and a common source of alternating current for supplying energy to the cathode and the output circuits and for applying potential to the input circuit.

4. An electric control device comprising a vacuum tube having a grid, a cathode and an anode, a switching device and a source of alternating current connected between said cathode and anode, a resistance connected in said anode circuit, a connection from said resistance to said grid circuit for maintaining a potential difference between said cathode and grid, and a circuit closing means for connecting a shunt path across said grid and cathode for reducing the potential difference between said grid and cathode.

5. In combination an electric discharge device having a cathode, an anode and an impedance control element, a source of alternating current for heating said cathode and for supplying alternating anode voltage to said device, an impedance element in the anode circuit of said electric discharge device, a relay in the anode circuit of said electric discharge device which normally carries insufficient current to cause its operation, a connection from said impedance element to said impedance control element for normally applying a uni-directional biasing potential to said control element, and means for removing said biasing potential to cause the operation of

said relay while maintaining current flow through said impedance.

6. In combination, an electric discharge device having a cathode, an anode and an impedance control element, a resistance, a relay, said resistance and said relay being in the anode circuit of said electric discharge device, a connection from said resistance to said impedance control element for applying sufficient biasing potential thereto so that the current flowing through said relay is insufficient to cause its operation, and means for removing said biasing potential to cause the relay to operate while maintaining current flow through said resistance.

7. A temperature control system, comprising a vacuum tube having a grid, a cathode and an anode, a relay in said anode circuit operable upon variation of current therein, an electric heater, electrically actuated means for varying the current through said heater, means for normally supplying a biasing potential to said grid, temperature responsive means for altering said biasing potential, and a common source of alternating current for supplying the cathode and anode current and the grid biasing potential of said vacuum tube, the current through said heater, and the current for operating the means whereby the heater current is varied.

8. In combination, an electric discharge tube having an electron emitting cathode, an anode, and an impedance control element, a source of alternating current, connections from said source for maintaining an alternating potential between the cathode and the anode, a device operated by the space current of said tube, means including an impedance in the cathode-anode circuit for deriving a potential from said source for normally maintaining a uni-directional potential difference between the control element and the cathode such as to prevent the operation of said device, and means for shifting said potential difference to a value permitting operation of said device while maintaining current flow through said impedance.

9. An electric relay comprising a vacuum tube having a cathode, grid and anode, a source of alternating current supplying said cathode and anode, an impedance in said anode circuit, a source of uni-directional potential for said grid obtained from the potential drop across said impedance, said impedance being common to the grid and anode circuits of said tube, and a shunt across said impedance for effectively eliminating said impedance from the grid circuit of said tube while effectively maintaining it in said anode circuit.

10. An electric relay for controlling a large current with a comparatively small current comprising a vacuum tube having a cathode, grid and anode, an impedance, and a path containing a contact point shunting said im-

pedance, said anode, impedance and cathode being in series with the output circuit of said tube; and said grid, impedance and cathode being in series with the input circuit of said tube, the operation of said contact point effectively removing said impedance from said input circuit while effectively maintaining it in said output circuit.

In witness whereof, I hereunto subscribe my name this 18th day of October, A. D. 1926.
WARREN A. MARRISON.

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