

May 18, 1937.

K. B. ELLER

2,080,411

THERMIONIC OSCILLATOR

Filed April 19, 1934

2 Sheets-Sheet 1

Fig. 1.

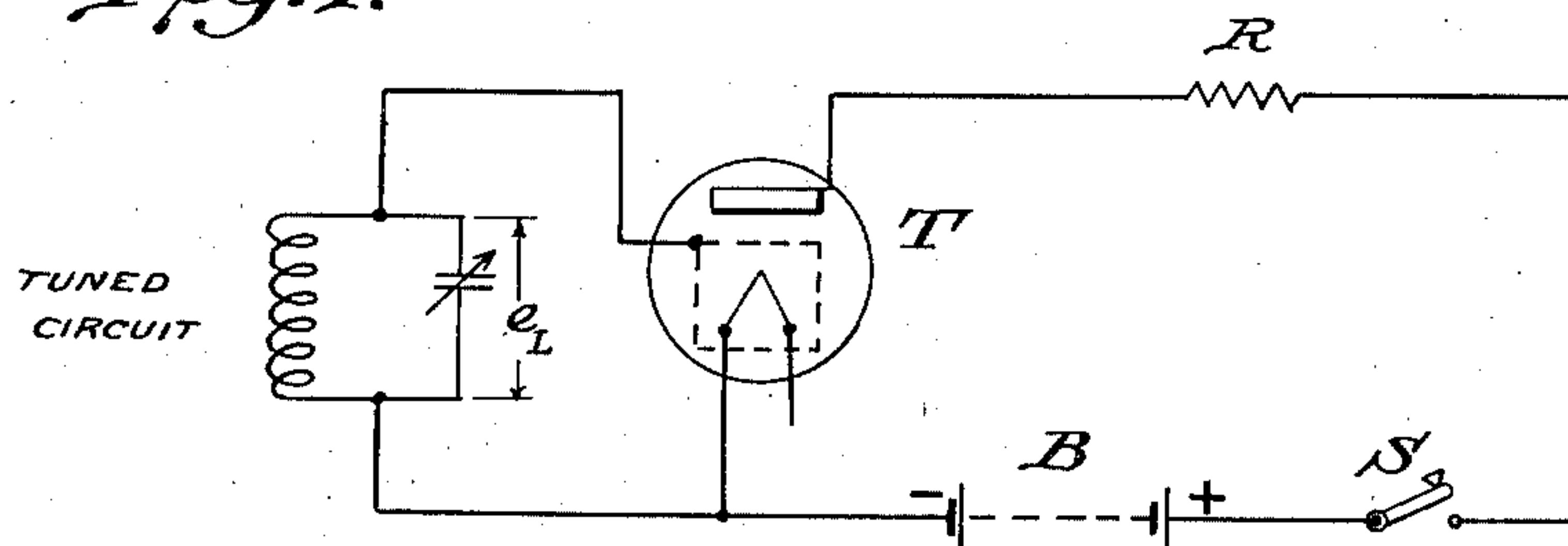


Fig. 2.

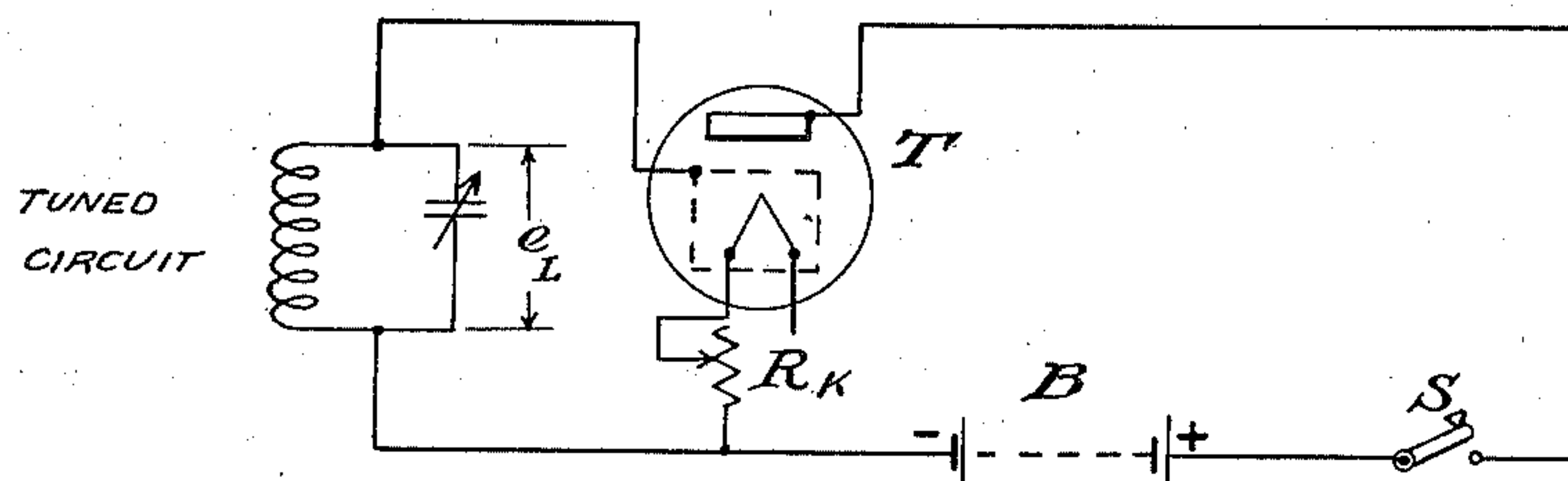
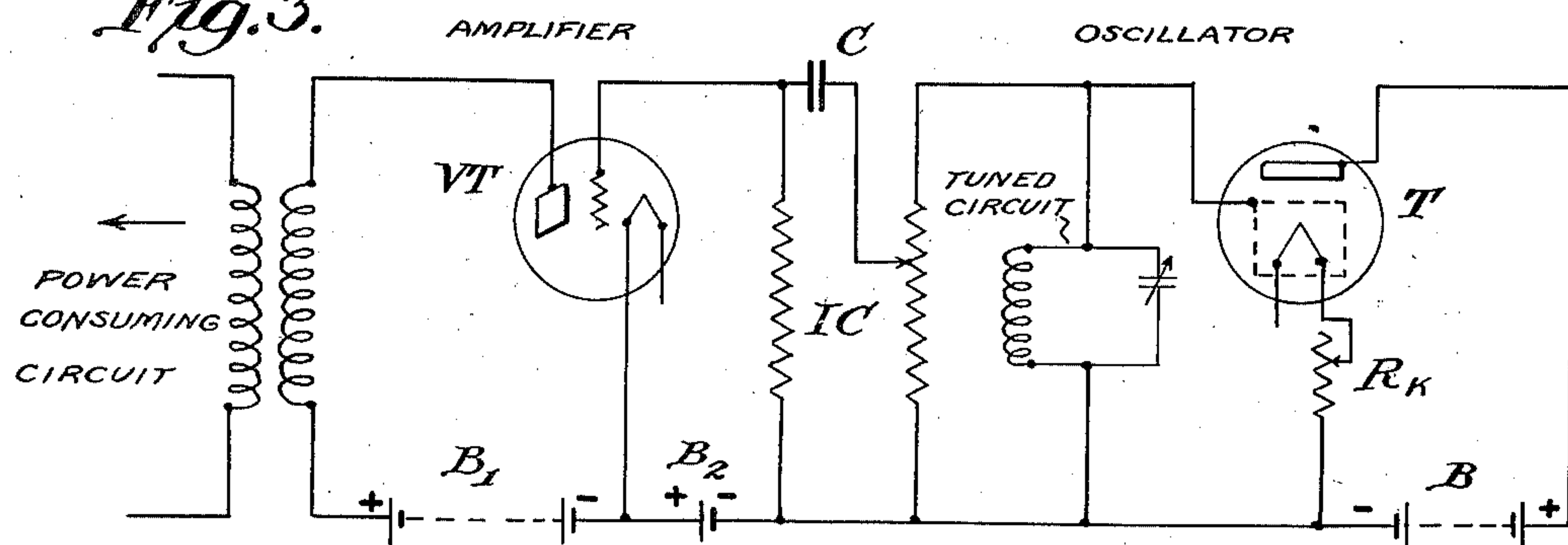


Fig. 3.



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Fig. 4.

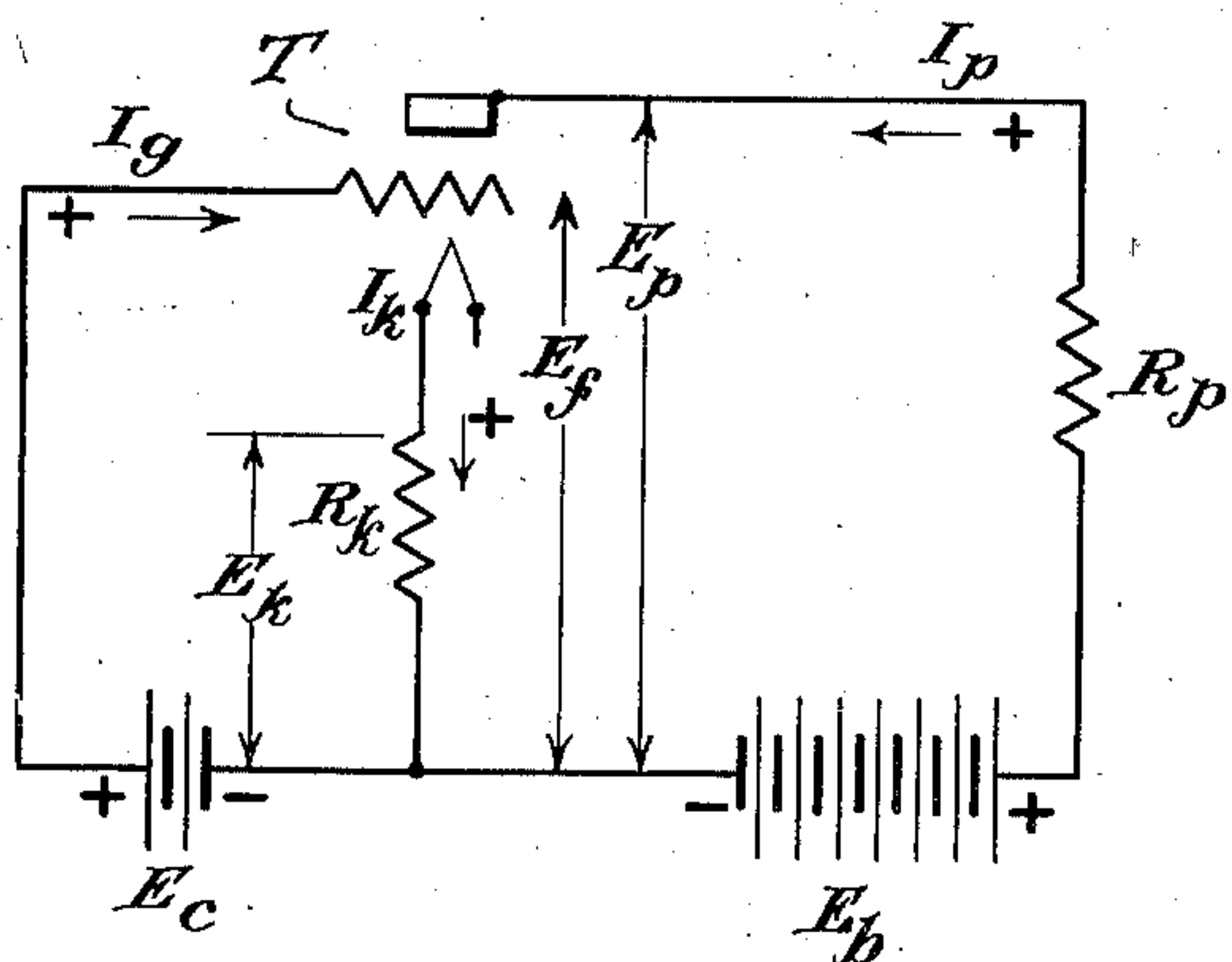


Fig. 5.

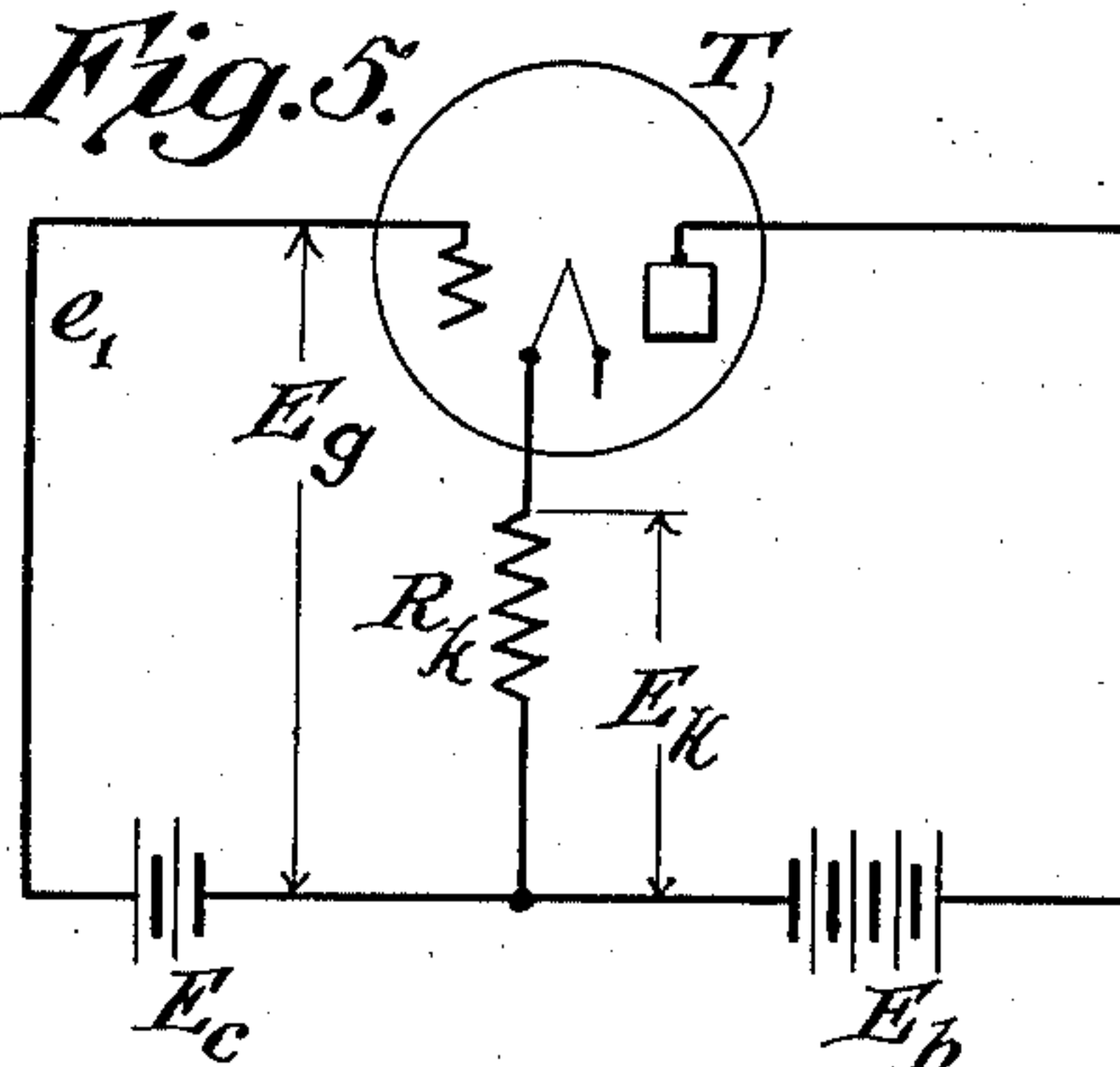


Fig. 7.

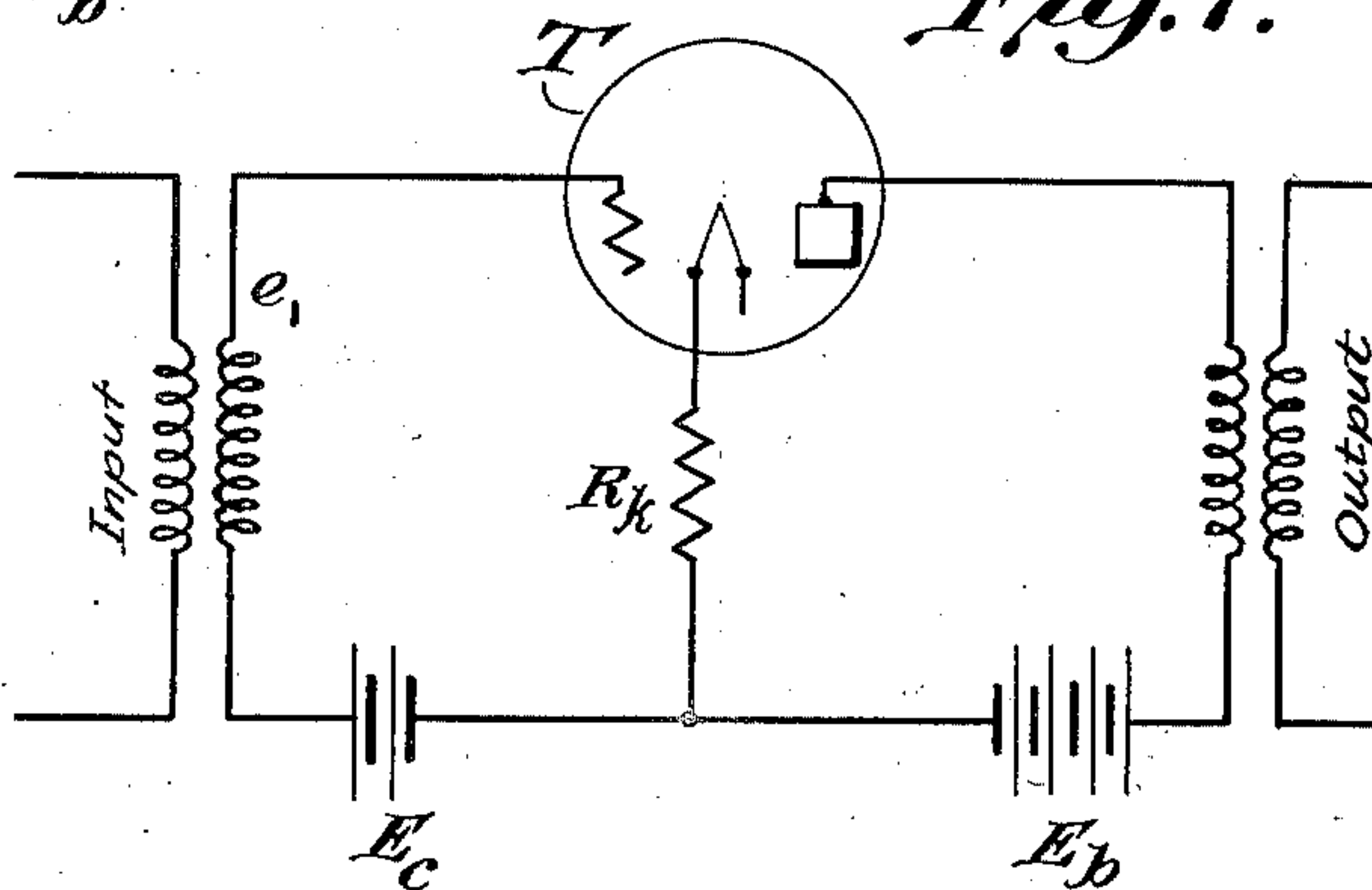
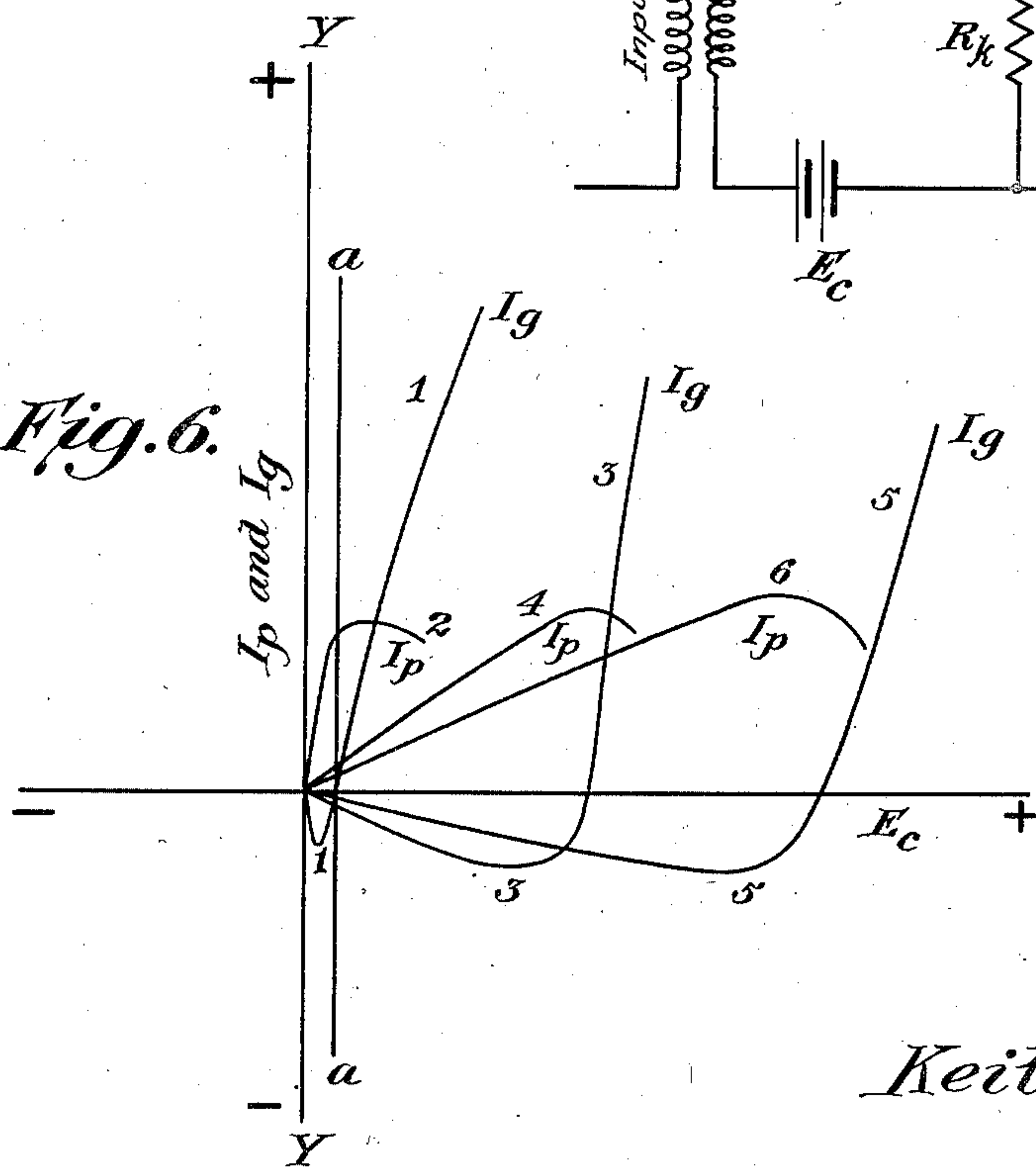


Fig. 6.



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UNITED STATES PATENT OFFICE

2,080,411

THERMIONIC OSCILLATOR

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Application April 19, 1934, Serial No. 721,391

10 Claims. (Cl. 250—36)

This invention relates to circuit arrangements for the production of continuous oscillations. The object of my invention is to produce an oscillation generator in which a resonant circuit is set into oscillation and is maintained in that condition by periodically impulsing or exciting the circuit in synchronism with the natural or free oscillations of the circuit by means of a thermionic tube of the gaseous type.

It has been proposed to provide alternating current generators by sustaining a tuned load circuit in continuous oscillation, exciting it with short impulses from an external source through an amplifier tube of the usual high vacuum type and providing an excessively high grid bias to permit the tube to be conductive only through a very short portion of the cycle. A further arrangement has been proposed in which the heavy grid bias is secured by means of a resistance, and employing the customary feed-back principles for sustaining the circuit in oscillation, a portion of the oscillatory circuit being shunted at all times by the cathode-anode circuit of the tube. The resistance of this cathode-anode circuit is always of a finite value, at times quite low, and hence produces a considerable damping effect upon the oscillatory circuit.

It is desirable that the tuned circuit shall have a low decrement, shall be extremely sharply tuned and of low resistance, so that the oscillations when started tend to persist for several cycles. An essential feature of my oscillating system consists of a thermionic tube of the start-stop type containing a gas or vapor at low pressure and of a construction in which the plate current starts with a low potential on the grid and is extinguished when the grid is made sufficiently negative. The construction of the tube is also such that over a small but definite range of grid-cathode potential, the plate current is a continuous function of that potential. A gaseous arc discharge tube of this type is disclosed and described in U. S. Patent No. 1,944,883 dated January 30, 1934.

The object of my invention is to provide an oscillating system having a great frequency stability; to provide a means of controlling the time required for the generated voltage to attain a steady state condition, to provide means for varying the steady-state output. The manner in which I attain these and other objects will be understood from the following description in connection with the accompanying drawings in which—

Figure 1 is a simplified diagram illustrating a circuit arrangement embodying the basic features of my oscillating system;

Figure 2 is a similar diagram but including a resistance common to the cathode, grid and plate circuits to stabilize and automatically extend the range of operation of the system;

Figure 3 illustrates a further embodiment of my invention wherein an auxiliary amplifier circuit is coupled by a high resistance means to the oscillatory grid circuit;

Figures 4, 5 and 7 are diagrams referred to in the following description of the characteristics of the basic circuit employed in my oscillating system;

Figure 6 is a graphic diagram showing the operating characteristics of the circuits illustrated in Figs. 4 and 5.

Before discussing the oscillating system disclosed herein, it may be well to analyze the characteristics of the basic circuit when used with the thermionic gaseous tube above referred to.

Referring to the circuit arrangement of Fig. 4 and the characteristics of the circuit as portrayed in Fig. 6, the curves I_g and I_p , representing the grid and plate current curves respectively, were obtained as follows:—

For a given value of cathode resistance R_k , the grid bias voltage, E_c , was varied from zero to a high positive value. (By zero grid voltage is meant that value for which the tube starts to ionize.) For various values of E_c the corresponding grid and plate currents were recorded. Curves 1, 3 and 5 show the grid currents, and curves 2, 4 and 6 show the plate currents for three different values of R_k . The sum of R_k and R_p was held constant for the three sets of curves. R_p serves as a current limiting resistance in the plate circuit.

As shown in Fig. 6, the grid current is negative over certain ranges of E_c . In fact, the grid current is negative over that range of E_c for which the plate current is approximately proportional to E_c . For the condition of $R_k=0$, this negative grid current region occurs between the vertical lines yy and aa .

The fact that the grid current is negative for certain values of the grid bias battery may be accounted for as follows: With the tube in an ionized state the grid may be considered as an "exploring wire" and as such will assume the approximate potential of the ionized gas at that point. The direction of flow of grid current will depend upon the relative values of the grid voltage, E_c , and the effective potential of the gas at the grid E_g . As E_c is made more positive, the plate current increases thus increasing the potential E_g due to the IR drop across R_k and thus

also increasing E_r . For a continued increase in E_c , E_r assumes a value greater than E_c and the grid current will reverse in direction. The negative grid current will flow from the plate circuit since E_r is more positive than E_k . That is, over the region of negative grid current $I_g = I_p - I_k$. For all positive values of E_c greater than E_r the grid current is positive.

The difference between E_c and E_k is obviously the grid-cathode potential. For conditions such that this difference is small (in the neighborhood of a few volts) the plate current will be controlled by the grid. The maximum variation of grid-cathode potential for which the grid acts as a continuous control element may vary somewhat as a result of external circuit constants.

The grid-cathode potential will automatically assume a value within this narrow range of control for all values of E_c such that E_c is less than E_k maximum. E_k (max.) is the value of E_k for maximum plate current. The maximum plate current is, of course, determined by the total resistance in the plate-cathode circuit, the range of E_c , for which the plate current is controlled by the grid, increases as R_k is increased. This characteristic is shown by the curves in Fig. 6, where curves 2, 4 and 6 give values of I_p for three successively increasing values of R_k .

Referring to the circuit shown in Fig. 5, consider the cathode resistance R_k to be the load resistance of an amplifier employing a gaseous tube such as described above. In such a device the output voltage E_k will be approximately equal to the voltage E_g (where E_g is the instantaneous sum of the input voltage e_i and the grid bias voltage E_c). The above statement is true only for positive values of E_g , since for negative values the plate current and consequently the output voltage are zero.

Assume a sinusoidal input voltage e_i of such a value that during no part of the cycle is the grid voltage E_g reduced to zero or increased to a value greater than E_k (max.), where E_k (max.) is as defined above. Under these conditions the circuit disclosed in Fig. 5 constitutes an amplifier, the amplification factor of which can be varied by changing R_k as indicated in curves 2, 4 and 6 of Fig. 6. The variable component e_k , of the output voltage E_k will be approximately equal to and in phase with the input voltage e_i . The output current will, however, be proportional to e_i .

Applying the principles and circuit characteristics above described, to the oscillating system of my invention and referring to Fig. 1, assume that the tube T (illustrated as of the gaseous start-stop type) is idle and that the plate circuit is open. Assume also that, as indicated in Fig. 6, the tube ionizes for zero potential between the grid and cathode. By appropriate tube construction the point at which the gas in the tube ionizes can be made to occur in either the positive or negative region of grid voltage. Upon closing the switch S, the plate current from battery B will start. There will flow simultaneously with the plate current a negative grid current, which will excite the tuned circuit. The initial surge of the voltage, e_L , induced in the tuned circuit by the grid current is necessarily in such a direction as to cause the grid to become positive. As shown by curve 1 of Fig. 6, a positive voltage thus applied to the grid circuit will cause the negative grid current to increase, which in turn, increases the induced voltage e_L .

The voltage across the tuned circuit will con-

sequently continue to increase for a period of time equivalent to one-quarter cycle of the resonant frequency. During the second quarter cycle the voltage e_L will return to zero, and during the negative half cycle of e_L , which carries the grid voltage to the left of the line yy , the plate current and consequently the grid current will be zero. For the condition of zero grid current there is little or no damping on the tuned circuit and it will tend to continue in a state of free oscillation. Thus, this type of gaseous tube oscillator differs greatly from the familiar three-element vacuum tube oscillator. In the latter case, energy is received by the resonant circuit during the entire cycle, while in the gaseous tube oscillatory circuit, energy is received only during that part of the cycle for which the grid-cathode potential is positive.

As the voltage, e_L , swings to positive, the tube again ionizes and the tuned circuit receives energy in an amount corresponding to the value of E_g . E_g is equal in this case to e_L . If the average energy received per cycle from the grid circuit exceeds that dissipated in the tuned circuit the system will be maintained in continuous oscillation.

While the arrangement above described will oscillate quite readily, I have found that the action of the oscillator is rendered more stable by the insertion of the resistance R_k as indicated in Fig. 2 where it is common to the cathode, grid and plate circuits. Referring to Fig. 2, assume the same tube and circuit conditions as those described in connection with Fig. 1, with the exception that a cathode resistance is inserted as shown. Upon closing the switch S, both plate and grid current will start in accordance say, with curves 6 and 5 respectively of Fig. 6. In quite the same manner as described in connection with Fig. 1, there will be set up and maintained an oscillatory voltage, e_L , across the tuned circuit.

The circuit shown in Fig. 2, however, offers several distinct advantages over that indicated in Fig. 1; namely, larger generated voltage across the tuned circuit, greater frequency stability, a means of controlling the time required for the generated voltage to attain steady state conditions and a means of varying the steady-state output.

The circuits disclosed in Figs. 1 and 2 will oscillate as described only over that portion of the characteristic for which the grid current is negative. As shown by the curves of Fig. 6, the range of external grid voltage E_g for negative grid current is increased by inserting a cathode resistance. From these facts it follows that the effect of increasing the cathode resistance is to allow the oscillating voltage e_L to build up to a larger value before the condition for positive grid current is reached.

The small range of grid-cathode potential for which the tube exhibits desirable characteristics has been shown to be in the immediate neighborhood of the starting voltage. With no cathode resistance this potential is obtained entirely from the external grid circuit. Any change in tube or circuit constants (such as temperature, filament current, plate supply voltage, etc.) may conceivably alter slightly the starting voltage and consequently shift this narrow control region. Such changes cause a general instability of the circuit since the bias voltage in the grid circuit is necessarily small.

The effect of the cathode resistance has been

seen to automatically maintain the grid cathode potential within the desirable range and at the same time allow a much larger amplitude of external grid voltage. Under such conditions a slight drift of the starting voltage will be relatively small compared to the controlling voltage. The stability of the circuit is consequently greatly improved.

The amplitude of the first positive peak of the generated voltage across the tuned circuit will depend, among other conditions, upon the magnitude of the initial surge of grid current.

Considering the effect of inserting a positive bias voltage in series with the tuned circuit of Fig. 2; upon closing the plate circuit the magnitude of the initial surge of grid current will depend upon the value of positive bias used. The energy transferred to the tuned circuit during the first half cycle will increase as the bias voltage is made more positive. By a proper adjustment of the bias voltage, the peak value of the initial cycle of the generated voltage can be made equal to the succeeding peaks.

Such a control of the time required to attain a steady state condition is important when a device such as herein described is used in numerous applications, such e. g. as a generator for a carrier telegraph system.

By reason of the relationship of the resistance to the several coacting circuits described, the generated frequency is remarkably independent of nominal changes of circuit constants such as plate voltage, grid bias and filament current. The resistance R_k , thus assists greatly in stabilizing the action of the oscillator. Moreover the frequency is readily controllable over a wide range.

It is evident that the oscillator above described is not capable in itself of producing any considerable amounts of power, since the oscillatory function is performed almost entirely within the grid circuit of the tube. It is true that a large current is circulating through the cathode-anode elements of the anti-resonant circuit, but it is not practicable to couple a power consuming circuit therewith since the resultant damping effect would then handicap the action of the circuit.

I have shown in Fig. 3 the manner in which a power consuming circuit may be connected to an oscillatory system by means of an auxiliary amplifier circuit coupled by a high impedance means IC to the oscillatory grid circuit. The grid circuit of the amplifier VT, (which may be a high vacuum tube) consumes only a negligible amount of energy but oscillatory power in any desired amount may be secured from the work circuit of the amplifier.

The circuit arrangement shown in Figs. 5 and 6, may be employed as an amplifier unit in a transmission system, as illustrated in Fig. 7.

It will be evident to engineers that the oscillatory system disclosed herein is not limited to the specific forms shown and described, and that various changes or modifications can be made within the scope of the invention.

I claim:—

1. In an oscillation producing system employing a gaseous arc discharge tube having anode, cathode and a grid or control element for starting and stopping the anode-cathode current and a resonant oscillatory circuit included in the grid circuit for determining the period of oscillations produced, the method of producing free oscillations in the resonant circuit unaffected by any damping due to cathode-anode losses which

comprises initiating a current in the cathode-anode circuit, producing a grid circuit current from the cathode electron stream to excite the resonant circuit and applying the negative potential of the second half cycle of the resulting oscillations to quench the tube, thereby rendering the resonant circuit independent of the tube constants.

2. In an oscillation producing system of the type employing an electron discharge device having an anode and cathode, a gaseous arc path between said anode and cathode, a grid element so formed that it controls the starting and also the stopping of the anode-cathode current, and a resonant circuit oscillatory unit in the grid circuit, the method of applying energy to the oscillatory unit which comprises initiating a current in the grid circuit from the gaseous arc in the anode cathode circuit periodically in synchronism with the natural oscillations of the oscillatory unit and causing the negative half cycle of the oscillations to stop said current.

3. In an oscillation producing system of the type employing a gaseous arc discharge device provided with an anode and cathode having a gaseous arc path therebetween, a grid element so formed that it controls the starting and also the stopping of the anode-cathode current, and a resonant circuit oscillatory unit in the grid circuit, the method of applying energy to the oscillatory unit which comprises initiating a current in the grid circuit from the electron stream in the anode-cathode circuit periodically in synchronism with the natural oscillations of the oscillatory unit, the starting and stopping of said arc being subject respectively to positive and negative potentials applied to the grid, the potential of the negative half cycle of the oscillations operating to extinguish the current in the anode-cathode circuit and the positive potential of the recurring positive half cycle operating to start the current in the anode-cathode circuit.

4. An oscillation generating system having an oscillatory circuit and a gaseous arc discharge device provided with anode and cathode elements and a grid or control element for starting and stopping the anode-cathode current, said oscillatory circuit forming a part of and being confined to the grid circuit of said discharge device, a current source for supplying energy to the anode-cathode circuit, and a resistance element common to the anode-cathode and grid-cathode circuits.

5. An oscillation generating system having an oscillatory circuit and a gaseous arc discharge device provided with anode and cathode elements and a grid or control element for starting and stopping the anode-cathode current, said oscillatory circuit forming a part of and being confined to the grid circuit of said discharge device, and a current source for supplying energy to the anode-cathode circuit, to normally cause the flow of current therein, said oscillatory circuit receiving energy from the cathode electron stream, the resulting cyclic potentials causing the grid to alternately stop and start the anode-cathode currents.

6. An oscillation generating system having an oscillatory circuit and a gaseous arc discharge device provided with anode and cathode elements and a grid or control element for starting and stopping the anode-cathode current, said oscillatory circuit forming a part of and being confined to the grid circuit of said discharge device, a current source for supplying energy to the

anode-cathode circuit, to normally cause the flow of current therein, said oscillatory circuit receiving energy from the cathode electron stream, the resulting cyclic potentials causing the grid to alternately stop and start the anode-cathode currents, and means responsive to the anode-cathode current to momentarily augment the negative stopping potential impressed on the grid due to the negative half cycle in the oscillatory circuit.

7. In combination, an oscillatory generating system comprising a gaseous arc discharge tube, having anode and cathode elements and a grid or control element for starting and stopping the anode-cathode current, an oscillatory circuit included in the grid circuit, a current source for supplying energy to operate the anode-cathode circuit, a resistance common to the anode-cathode and grid circuits, an amplifier circuit coupled to said grid oscillatory circuit, and a work circuit connected to receive energy from said amplifier circuit.

8. An oscillatory generating system, comprising a gaseous arc discharge tube having anode and cathode elements and a grid element operating to control the starting and stopping of the anode-cathode current, a resonant oscillatory circuit included in the grid circuit of the tube, a

current source for supplying the anode-cathode current, said oscillatory circuit being actuated by said current source through conduction within the tube.

9. An oscillatory generating system, comprising a gaseous arc discharge tube having anode and cathode elements and a grid element operating to control the starting and stopping of the anode-cathode current, a resonant oscillatory circuit included in the grid-circuit of the tube, a current source for supplying the anode-cathode current and means to cause the grid current to increase in a negative direction as the positive potential on the grid is increased.

10. An oscillatory generating system, comprising a gaseous arc discharge tube having anode and cathode elements and a grid element operating to control the starting and stopping of the anode-cathode current, a resonant oscillatory circuit included in the grid circuit of the tube, a current source for supplying the anode-cathode current, said oscillatory circuit being energized by the voltage generated in the grid circuit and means included in the grid circuit for controlling the time required for said generated voltage to attain a steady value.

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