Dec. 28, 1937.

L. K. SWART

2,103,439

GAS-FILLED TUBE

Filed April 9, 1935

2 Sheets-Sheet 1

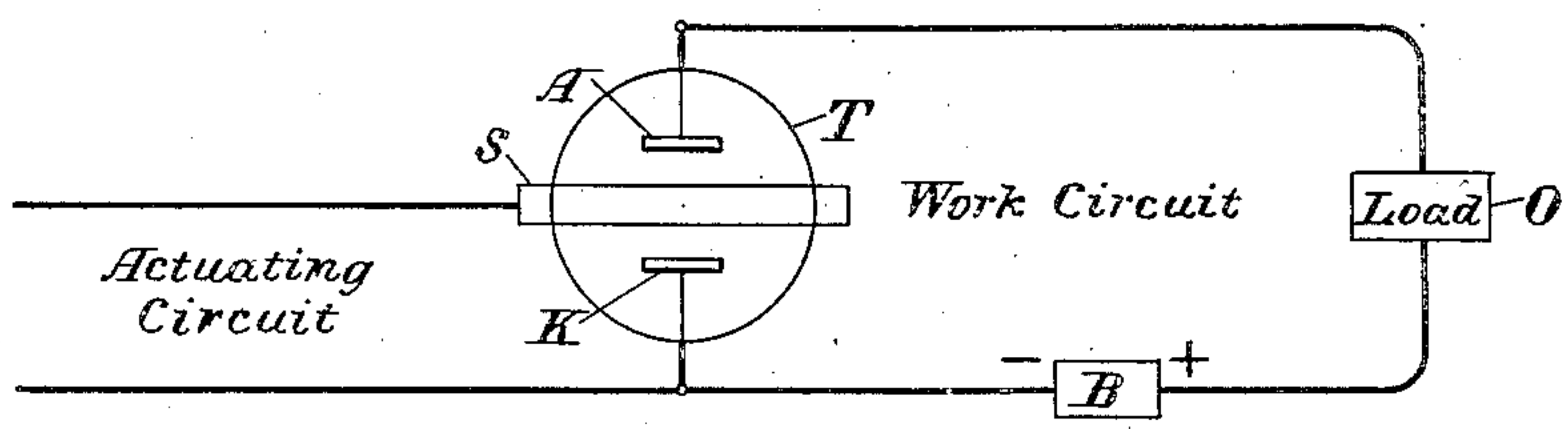


Fig. 1

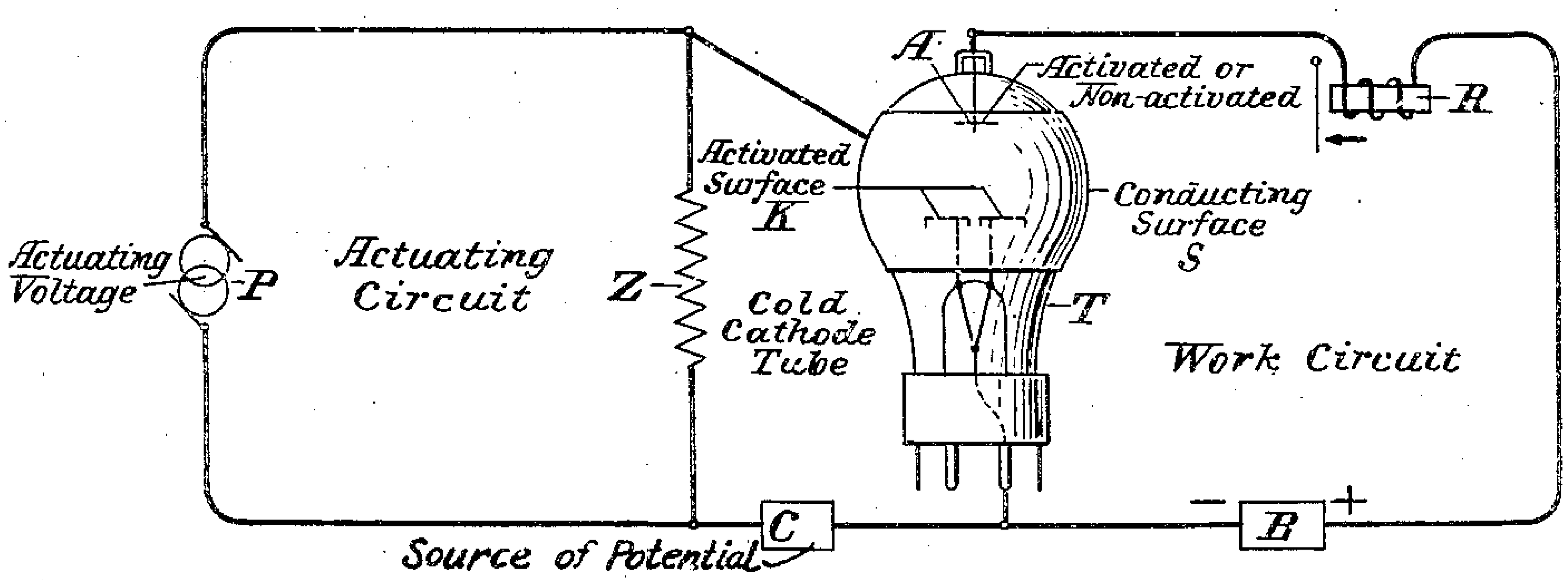


Fig. 2

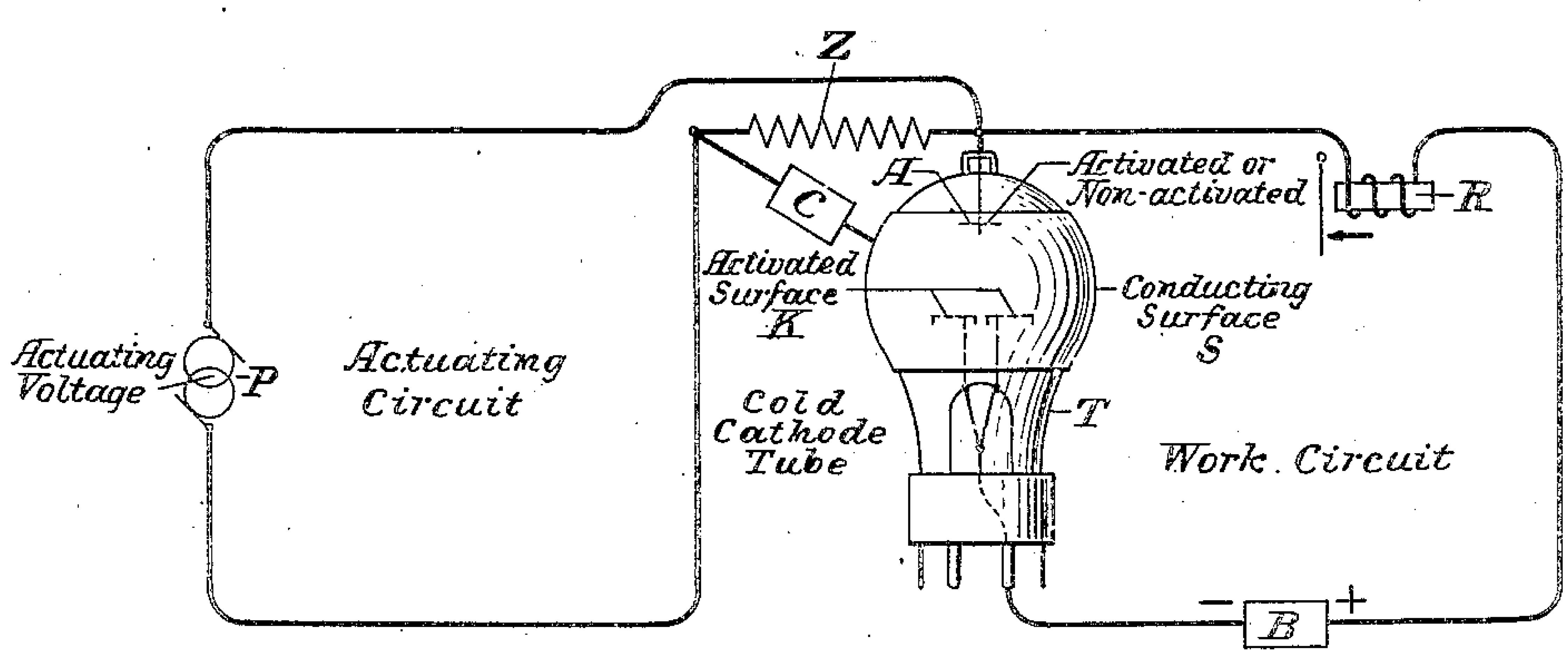


Fig. 3

INVENTOR
L. K. Swart
BY
ATTORNEY

GAS-FILLED TUBE

Filed April 9, 1935 2 Sheets-Sheet 2

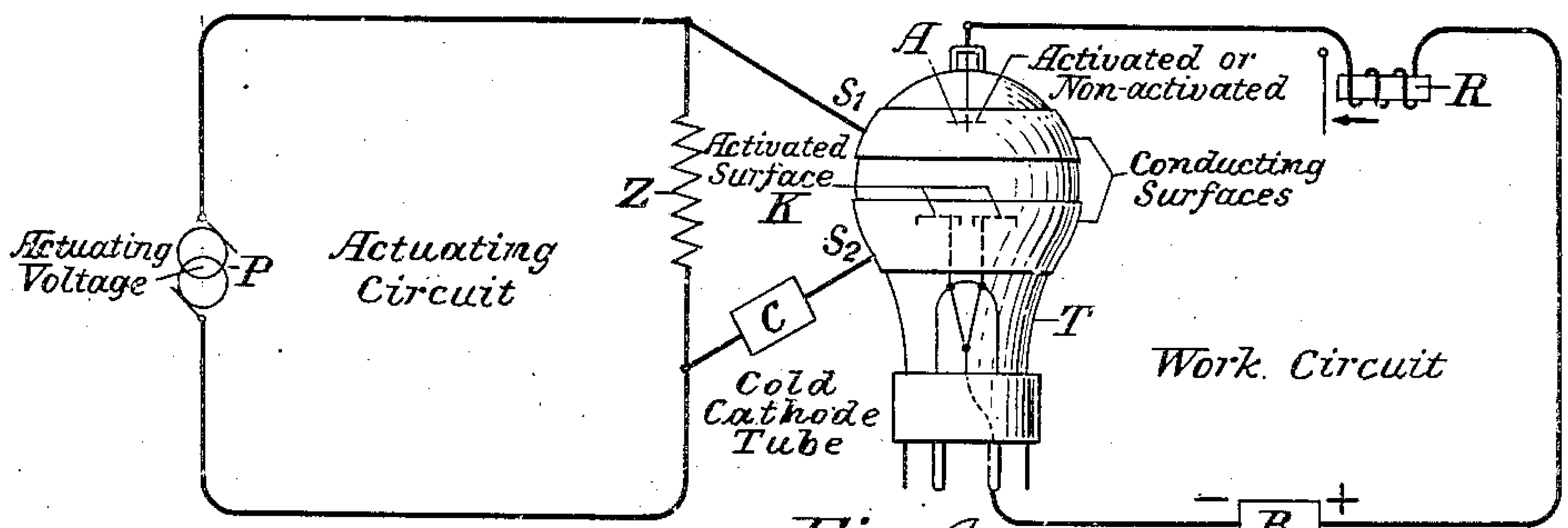


Fig. 4

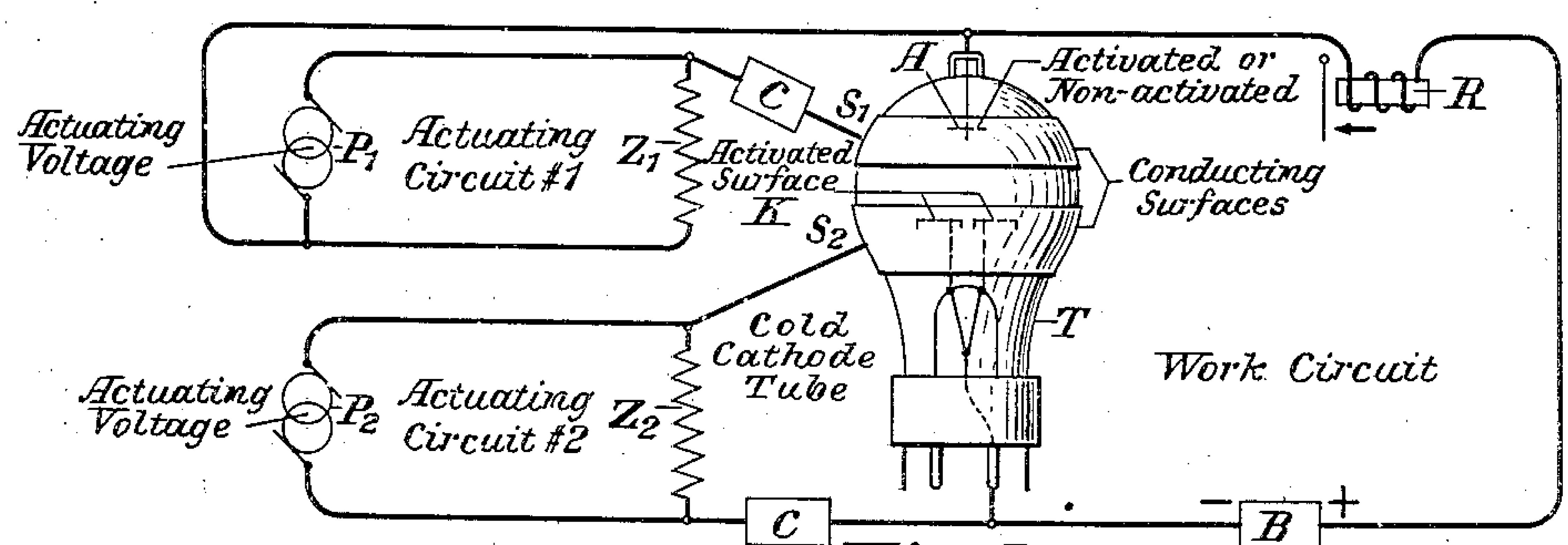


Fig. 5

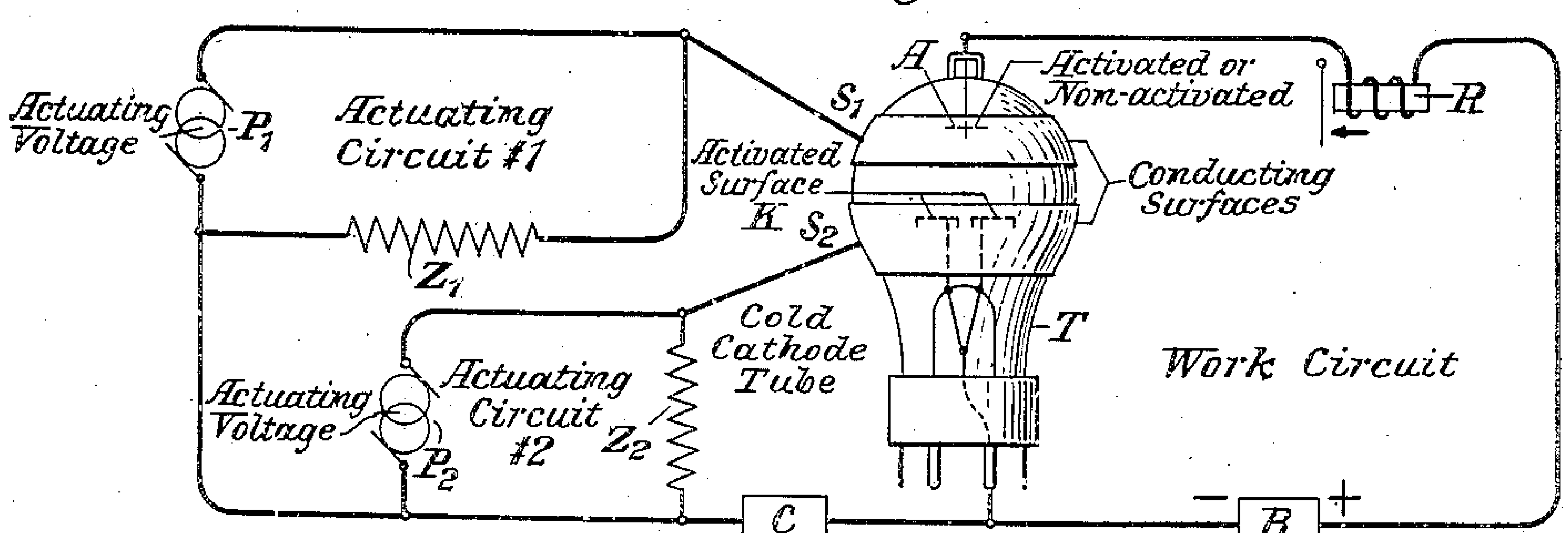
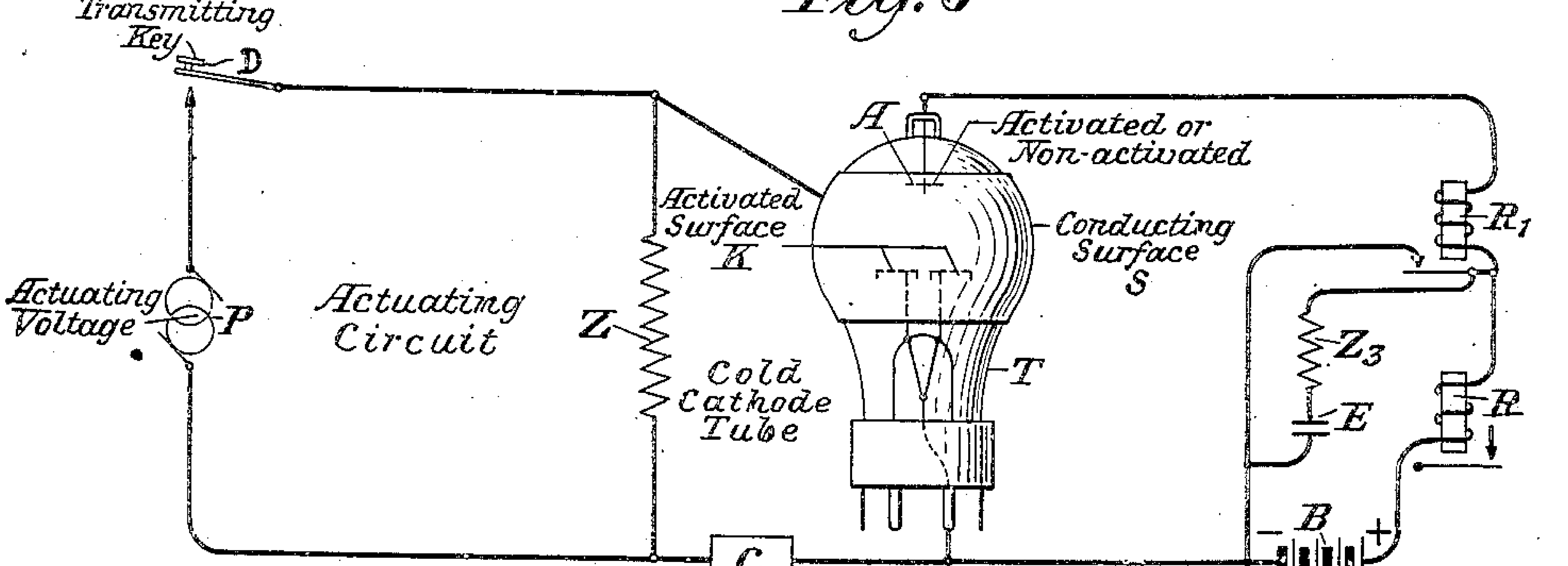


Fig. 6



Source of Potential

Fig. 7

INVENTOR
L. K. Swart

BY [signature]
ATTORNEY

Patented Dec. 28, 1937

2,103,439

UNITED STATES PATENT OFFICE

2,103,439

GAS-FILLED TUBE

Leland Kasson Swart, Mountain Lakes, N. J., assignor to American Telephone and Telegraph Company, a corporation of New York

Application April 9, 1935, Serial No. 15,482

11 Claims. (Cl. 250—27)

This invention relates to gas-filled tubes. More particularly, this invention relates to gas-filled tubes having solid electrodes. Still more particularly, this invention relates to gas-filled tubes having solid electrodes between which a gaseous discharge may take place. This invention also relates to circuits for operating such devices and for maintaining them in operation for long periods of time.

A gas-filled tube generally consists of two or more spaced electrodes enclosed within an envelope such as glass, filled with a gaseous medium such as neon, argon, helium or krypton, or a combination of these gases, or a combination of these gases and other gas or gases such as nitrogen. The electrodes of the tube are usually so spaced within the envelope that when a voltage exceeding a predetermined value, known as the breakdown voltage of the tube, becomes impressed across two of its electrodes a bluish and luminous glow discharge will occur between these electrodes. This luminous discharge will continue just as long as a somewhat lower voltage, known as the sustaining voltage, remains impressed across the aforementioned two electrodes. Immediately upon the discharge, and throughout its entire duration, the impedance between all of the electrodes of the tube will be reduced from an almost infinite value to a low and practically negligible value.

In accordance with this invention a modified form of gas-filled tube is involved and it consists of a gas-filled envelope within which there are two or more suitable electrodes both of which are always in contact with the gas within the envelope. An additional electrode is located external to the envelope. This external electrode may be spaced from the envelope or directly in contact therewith, and it may assume any desired shape as, for instance, a band or bands surrounding the envelope. Gas within the tube will be normally de-ionized and there will be no glow or ionization within the tube until a sufficient potential becomes applied to the external electrode and some internal electrode provided but a single external electrode is employed. When this occurs, however, the gas within the tube suddenly becomes ionized and a glow discharge appears therein. Under these conditions the impedance between all of the electrodes within the tube becomes greatly reduced to a negligible value. In other words, the tube is normally inert and consumes no current, but when required to operate current can flow through the tube only when a sufficient potential is applied to the external electrode.

This invention will be better understood from the detailed description hereinafter following when read in connection with the accompanying drawings, in which Figure 1 shows an arrangement employed for the purpose of explaining some of the principles of this invention; Fig. 2 shows the invention applied to one form of gaseous discharge tube obtainable in the open market; Fig. 3 shows an arrangement which is a modification of the one shown in Fig. 2; Figs. 4, 5 and 6 show other arrangements each of which includes a gaseous discharge tube having two external electrodes, and Fig. 7 shows an arrangement in which the principles of this invention may be applied to signalling systems.

Referring to Fig. 1 of the drawings, the reference character T designates a tube the envelope of which is filled with an inert gas of a composition usually inserted in such devices. A plurality of electrodes may be enclosed within the envelope of this tube but only two such electrodes are shown in Fig. 1 merely for the sake of illustration, and these are designated A and K. They will be referred to hereinafter as the anode and cathode, respectively. The circuit connected to the anode A and the cathode K will be designated the work circuit, and in Fig. 1 this work circuit may include a source of potential B and a load O. The source B may be one of continuous direct current, or of interrupted direct current, or of alternating current, as will be more fully described hereinafter. It is essential, however, in the practice of this invention that the effective potential of the source B be less than the breakdown voltage of the tube, but greater than the voltage required to sustain a discharge within the tube after it is started.

The electrode S is in the form of a conductive or metallic band external to the envelope of the tube, and it may surround the envelope. The actuating or input circuit of this arrangement may be connected between the external electrode S and one of the internal electrodes A or K, but for the sake of illustration this actuating or input circuit is shown as connected between the electrodes S and K.

If no potential is applied between the external electrode S and the electrode K through the actuating circuit, the potential of the source B will be insufficient to initiate ionization of the gas within the envelope of the tube T. No current will then flow through the tube and the work circuit will therefore be unoperated. As soon as sufficient potential is applied to the actuating circuit connected to the external electrode S and the internal electrode K, the gas within the tube will become ionized and a discharge will then occur within the tube. This discharge will reduce the impedance between the electrodes A and K to a negligible value and current will then flow from the source B, through the load O and over the work circuit. In other words, the work circuit will be started in operation only when a sufficient potential is applied between the external electrode S and one of the internal electrodes of the tube T.

If the source B is one of continuous direct current, such as a storage battery, and poled so that the anode A is rendered positive with respect to the cathode K, the potential of the source being greater than the sustaining voltage but less than the breakdown voltage of the tube, the application of a sufficient potential between the external electrode S and the internal electrode K will initiate ionization within the tube, as already explained. Now, if the potential applied between the electrodes S and K is such that the electrode S is rendered sufficiently positive with respect to the cathode K, the initiation of ionization within the tube will take place particularly because of the potential impressed between these electrodes S and K. After ionization takes place current will continuously flow from the battery B through the load O and over the work circuit which extends to the electrodes A and K, and this work circuit will be continuously energized irrespective of the potential applied to the actuating circuit. In other words, the work circuit will be continuously operated even when the potential applied between the actuating electrode S and the cathode K is removed. The work circuit can be returned to its normal and unoperated condition by de-ionizing the gas within the tube, and this may be accomplished, for instance, by opening the work circuit, as for example, by means of a switch (not shown).

If, however, the potential applied between the external electrode S and the cathode K is such that the external electrode is rendered sufficiently negative with respect to the cathode K, this potential of the actuating circuit will be effectively in series with the potential of the source B and both potentials will be additive and may create a sufficient potential between the electrode S and the anode A so as to ionize the gas within the tube T. In other words, the actuating potential may be such as to bring about a voltage effect between the electrodes S and A sufficient to ionize the gas within the tube. When this occurs the work circuit will again be operated and current will continuously flow from the source B through the load O and over the work circuit. Again the work circuit may be returned to its normal condition and the gas within the tube de-ionized by opening the work circuit or by other means, and if the work circuit is not returned to its normal condition current will continuously flow from the source B irrespective of the presence or absence thereafter of potential between the electrodes S and K.

If the source B were one which produced interrupted direct current the potential of which was greater than the sustaining voltage and less than the breakdown voltage of the tube T, ionization within the tube T may be initiated by applying a sufficient potential between the electrodes S and K, and a pulsating current will therefore flow through the load O and over the work circuit. This pulsating current will cease just as soon as the potential applied to the actuating circuit is removed or is rendered ineffective. Similarly, if the source B is one of alternating current, alternating current or rectified current depending upon tube design will flow through the work circuit only as long as sufficient potential is applied to the actuating circuit. In other words, the tube will automatically reset itself so that the gas therein will become de-ionized immediately after the applied potential is removed from the actuating circuit in those cases in which the source B is a pulsating potential or an alternating potential. If, however, the source B is a continuous direct potential, any of the circuits shown in my Patent No. 1,977,256, issued October 16, 1934, may be used for the purpose of resetting the circuit to normal.

The tube T encloses two electrodes both of which are solid electrodes which are spaced from each other by a predetermined distance. This tube may, of course, include many more than two electrodes if desired, and any two of the electrodes may be used for connection to some form of work circuit. In fact, each pair of electrodes may form individual circuits all simultaneously controlled by a single actuating circuit. Also each work circuit may include a common electrode within the tube and one of the other electrodes, all of the circuits being simultaneously controlled by a single actuating circuit.

It will be further noted that the electrodes A and K of the tube T are shown as flat plates which face each other. These electrodes may be circular or rectangular in shape, or of any other shape; and they need not be flat, they may be curvilinear, that is, either convex or concave, to any desired degree. If the electrodes are of equal area, as shown in Fig. 1 of the drawings, the work circuit may be completely reversed so that the source B may apply, for instance, negative potential to the electrode A and a positive potential to the electrode K. Under such conditions with alternating potentials supplied at B a substantially equal current will flow in either direction through the work circuit after ionization is initiated by supplying a sufficient potential to the actuating circuit. These electrodes A and K need not be equal flat plates, however, but may be of any configuration or one or both may be pointed if so desired. If a pointed electrode is enclosed within the tube it is preferable, however, that the source B be so poled as to render the pointed electrode positive with respect to the other electrode. A somewhat greater current will flow through the work circuit under such conditions than when the work circuit is reversed so as to reverse the polarity of the source B applied between the pointed electrode and the flat electrode.

Although the external electrode S is shown in the form of a metallic band the plane of which is perpendicular to and bisects the gap formed by the electrodes A and K of the tube T, such an arrangement is by no means essential. The electrode S need not surround the envelope of the tube and it need not lie in a plane which is perpendicular to the direction of the gap between electrodes A and K; the electrode S may form any desired angle with respect to the direction of the gap formed by electrodes A and K.

The electrodes A and K, and any other electrodes enclosed within the envelope of the tube, may, if desired, be coated with an activating material of any type well known in the art. This is not an essential requirement for the operation of any of the arrangements employed in this invention, but if the internal electrodes are so coated the efficiency and stability of operation of the tube will be increased and, moreover, a lower potential will be required, not alone for initiating ionization within the tube, but a lower potential will also suffice to continuously maintain ionization within the tube.

Fig. 2 shows a tube T which resembles a type of cold cathode discharge tube familiar to those skilled in this art. This tube T includes within its envelope a pointed anode A and two cathodes which are spaced from each other but which are, in this invention, connected to each other so as to form a single cathode K. The commercial type of tube T, however, is improved in accordance with this invention by the presence of an external electrode S which is a conducting surface placed about the envelope of the tube T, as shown.

The work circuit of the tube T includes not alone the anode A and the cathode K of the tube T, but also a source B and the winding of a relay R which are in series with each other. The external electrode S is connected to the cathode K by means of a resistance Z and a source C which is used for biasing the external electrode S with respect to the cathode K. A source of actuating voltage P in the form of an alternating current generator is connected across the impedance Z.

The source C, although it biases the external electrode S with respect to the cathode K, is insufficient by itself to initiate ionization of the gas within the tube T. It is necessary that the actuating voltage P be applied through the impedance Z, between the external electrode S and the cathode K, in addition to the effect of the source C to initiate ionization of the gas within the tube. It seems hardly necessary to state that after ionization is initiated current flows from the source B through the work circuit and operates the relay or other load R. If the source B is one of continuous direct current the relay or load R will be continuously operated until the work circuit is opened, or if a resetting circuit is employed, until the gas within the tube T is otherwise restored to a de-ionized state. If the source B is a pulsating potential or an alternating potential, the work circuit will be restored to its initial condition and the relay or load R will become unoperated upon removal of the applied voltage P.

The impedance Z is employed for the purpose of removing any charge upon the conducting surface S after the actuating voltage P has been disconnected from the circuit. Any charge on the external electrode S will leak back to the cathode (or ground) through Z and this leak will occur whether or not a biasing source of potential C is employed.

It will be understood that the actuating voltage need not be an alternating potential. It may be a sufficient direct potential, or any other form of potential. It is the combined effect of the actuating potential P and the biasing potential C, where the two are sufficiently large, that produces ionization of the gas within the tube T. If however, the combined effect of the sources P and C is such as to render the external electrode S positive with respect to the cathode K, and the source B is such as to render the anode A positive with respect to the cathode K, ionization will take place by virtue of the initial potential applied between the electrodes S and K. If the combined effect of the sources P and C is such as to render the external electrode S negative with respect to the cathode K, this combined effect will produce between the external electrode S and the anode A a voltage which is aided by the source B. This potential applied between the electrodes S and A may be sufficient to ionize the gas within the tube T and bring about the operation of the work circuit.

It will be understood that if the source B produces a pulsating potential or an alternating potential of such a character that the interval between applications of voltage between the electrodes A and K is less than the time required to de-ionize the gas within the tube T, the gas within the tube T will remain continuously ionized irrespective of the application of any potential to the external electrode S. The work circuit may then be returned to normal by removing or otherwise suppressing the actuating voltage P, as already described hereinabove.

It will be further understood that the source C is not indispensable in the practice of this invention. It may be entirely eliminated in which case there would be no bias between the external electrode S and the cathode K. Under such conditions the actuating voltage would itself bring about the initiation of ionization by applying potential to the external electrode S and one of the other internal electrodes of the tube.

It will be still further understood that in the tube T, as in each of the other tubes to be hereinafter described, the anode A and the cathode K, may both be solid, metallic elements of equal area in which case the work circuit may be reversed without in any way appreciably affecting its operation.

Fig. 3 is a modification of the arrangement shown in Fig. 2 in which the source C biases the anode with respect to the external electrode S, the biasing potential C being applied through the impedance Z. This arrangement operates in the manner already described with respect to Fig. 2.

Fig. 4 shows a tube T the work circuit of which is connected between the anode A and the cathode K, as in Fig. 2. The tube T of this arrangement, however, has two external conducting electrodes S_1 and S_2, both of which are for convenience wrapped about the envelope of the tube and are normally insulated from each other. Neither of these external electrodes is connected to the anode A or the cathode K of the tube T, or to the work circuit which is connected to these electrodes.

The leak impedance Z is connected between the external electrodes S_1 and S_2 through the biasing battery C, but it will be apparent that neither the battery C nor the impedance Z is essential to the operation of the system. As in Figs. 2 and 3 the actuating voltage P may take the form of a generator of alternating current which produces a potential across the terminals of the impedance Z. In this arrangement the biasing potential C is insufficient alone to initiate gaseous ionization within the tube T, but the additional voltage derived from the actuating source P and applied between the electrodes S_1 and S_2 is sufficiently large to initiate ionization. Thus a discharge occurs between the electrodes A and K, and the work circuit is then supplied with current from the source B.

The tube T and its conductive external electrodes S_1 and S_2 are admirably adapted for signaling circuits in which one of the circuits of the system may be conductively dissociated from another of the circuits of the system. In a telegraph system, for instance, the electrodes S_1 and S_2 may be connected to one of the circuits, and the anode A and cathode K may be connected to another of the circuits. No current will flow through the circuit of the anode and cathode until a sufficient voltage, properly poled, becomes applied to the electrodes S_1 and S_2. The circuit of Fig. 4 is especially useful because there need be no conductive connection between either of the external electrodes and either of the internal electrodes under normal conditions, and conductivity may occur only after gaseous ionization has been initiated.

Fig. 5 is a modification of the arrangement of Fig. 4 in which the tube T includes two external electrodes S_1 and S_2, and the work circuit is the same as that shown in Fig. 4, but two separate actuating voltages are derived from sources P_1 and P_2. The source P_1 may apply a sufficient potential between the external electrode S_1 and the internal electrode A, the voltage being applied through the impedance Z_1 and biasing source C. The source P_2 may also supply a sufficient actuating voltage, but this voltage is applied between external electrode S_2 and the cathode K through the impedance Z_2 and the biasing source C. The application of either of the potentials of sources P_1 or P_2 will be sufficient to initiate ionization of gas within the tube T, and the work circuit will be operated when either of these potentials of sufficient amplitude becomes applied between the associated external electrode and the corresponding internal electrode.

Fig. 6 is a modification of Fig. 5, in which either of the actuating voltages derived from sources P_1 and P_2 may produce a sufficient potential between the corresponding external electrodes S_1 or S_2 and the cathode K of the tube T to produce ionization of the gas. The voltage P_1 may be applied between the electrode S_1 and cathode K, through impedance Z_1 and the source C, while the voltage P_2 may be applied between the external electrode S_2 and cathode K, through impedance Z_2 in the same source C. Either of the sources here also will produce sufficient voltage to initiate gaseous ionization within the tube T. Either source may employ individual C bias and the arrangements are not restricted to a common C bias as shown.

Fig. 7 is a modification of the arrangement shown in Fig. 2. Here the source P is connected to the impedance Z through a transmitting key D. The source B and the winding of the relay R are connected in series with each other and in series with the winding of a vibrating relay R_1. The negative terminal of the source B is connected to the lower terminal of the winding of the relay R_1 through a condenser E and a resistance Z_3 which are connected in series with each other. The contact of the relay R_1 is also connected to the negative terminal of the source B.

When the key D is open, gas within the tube T will be de-ionized and no current will flow from the source B through the windings of either of the relays R or R_1. When the key D is closed the actuating voltage P will be applied through the resistance Z along with the biasing source C between the external electrode S and the cathode K of the tube T. Ionization of the gas within the tube T will be initiated and a substantial current will then flow from the source B through the windings of the relays R and R_1. The relay R will remain operated as long as the key D is closed, but the relay R_1 will vibrate continuously throughout the entire interval during which the key D is closed. Upon the subsequent opening of the key D the relays R and R_1 will return to normal.

The condenser E may be a fixed condenser of any suitable value as, for example, two microfarads. The resistance Z_3 may be any suitable resistance as, for example, one having 20 ohms of resistance. These elements of capacity and resistance are bridged across the armature and contact of the relay R_1 for the purpose of preventing re-ionization of the gas within the tube T after it has been extinguished. This is accomplished as follows:

As already stated, the armature of the relay R vibrates, but its vibration is at high speed. Inasmuch as the winding of the relay R is in series with the source B, the periodic making and breaking of the circuit may cause the winding of the relay R to produce a sufficient voltage which, when added to that of the source B, will exceed the breakdown voltage required to initiate and maintain ionization between the electrodes A and K of the tube T. However, when the contact of the relay R_1 is opened the condenser E, being in a discharged state, effectively acts like a short circuit to suppress the voltage between the anode A and the cathode K. Consequently, the voltage produced across the winding of relay R will be ineffective in producing any potential between the electrodes A and K of the tube T. When the armature of the relay R_1 subsequently closes its contact, the condenser E will then discharge over the circuit which includes the resistance Z_3 and the armature and contact of the relay R_1. It will be further noted that when the armature of relay R_1 closes its contact, the electrode A will be connected to the electrode K through the winding of the relay R_1 and its armature and contact. Consequently, the battery B will at that time be ineffective in producing any appreciable voltage between these same electrodes A and K.

It will be understood that the impedances Z, Z_1 and Z_2 need not be resistors, but that they may be replaced by inductors or capacitors or autotransformers or two or more winding transformers, or any other similar device, as will be apparent to those skilled in this art.

The tube which forms the basis of this invention is one in which a luminous glow discharge occurs within the tube when it operates. Such a device is fundamentally different from devices which employ spark discharges. Moreover, the tube is a rather inexpensive device requiring little if any maintenance. It is highly efficient, and no current is required to maintain or prepare it for subsequent operation. It therefore differs from any device which employs a heated cathode or a mercury pool which requires a continuous arc so that it may be ready for any subsequent operation. The tube of this invention, although no current flows through it until it operates, is brought into operation only when a sufficient potential is applied to an external electrode. Furthermore, the internal electrodes of the tube are hard metallic substances which are continuously maintained at a low temperature, and this tube is admirably adapted for use in movable vehicles or devices such as automobiles, trains, airplanes, or the like. The potential applied to the external electrode is never enabled to prevent continuous gaseous ionization within the tube. In other words, the potential applied to the external electrode merely initiates operation, but has little if any subsequent control thereover.

While this invention has been shown and described as embodying certain features merely for the purpose of illustration, it will be understood that it can be used in many other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. The combination of a gas-filled tube enclosing two solid unheated substantially equal metallic electrodes spaced from each other, an electrode mounted external of the envelope of the tube, and means including a second electrode mounted external to the envelope of the tube for applying a potential between the first-mentioned external electrode and the second-mentioned external electrode so as to produce gaseous ionization between the internal electrodes of the tube, the circuit of the internal electrodes being uncontrolled by the external electrodes after gaseous ionization has been initiated.

2. The combination of a gas-filled tube having two solid unheated substantially equal metallic electrodes spaced from each other and an external electrode, means including a second external electrode for applying a potential between the two external electrodes for initiating ionization of the gas within the tube between its internal electrodes, and means connected to the internal electrodes for continuously maintaining the gaseous ionization within the tube independently of the presence or absence of potential between the external electrodes.

3. The combination of a gas-filled tube enclosing two solid unheated substantially equal metallic electrodes spaced from each other and having two external electrodes, a source of potential connected between the internal electrodes the magnitude of which is insufficient to break down the gap between the internal electrodes but is greater than that required to maintain gaseous ionization within the tube after it is started, means for applying a source of potential between the external electrodes for initiating gaseous ionization within the tube, and a load connected to the internal electrodes of the tube which becomes continuously operated after gaseous ionization is initiated and is thereafter independent of the magnitude or polarity of the potential applied to said external electrodes.

4. The combination of a gas-filled tube having two internal electrodes and two external electrodes, the internal electrodes being hard metallic elements, a source of potential, a load connected in series with the source of potential between the internal electrodes of the tube, a leak resistor connected between the external electrodes, and means for applying a potential across the leak resistor so as to initiate gaseous ionization within the tube and for continuously operating the load thereafter independently of the removal of the voltage applied across the leak resistor.

5. The combination of a gas-filled tube having two hard metallic internal electrodes and two external metallic electrodes, means for biasing one of the external electrodes with respect to the other of the external electrodes, means for applying a potential between the external electrodes so as to initiate gaseous ionization within the tube, and means connected to the internal electrodes of the tube for continuously maintaining gaseous ionization within the tube uninfluenced by transient variations in the magnitude, polarity or phase of the potential thereafter remaining or thereafter applied to said external electrodes.

6. The combination of a gas-filled tube having two hard metallic internal electrodes and two external electrodes which are spaced and insulated from each other, a work circuit connected between the internal electrodes of the tube, and means for applying potential between the external electrodes for initiating gaseous ionization within the tube and for continuously operating the work circuit uninfluenced by transient variations in the magnitude, polarity or phase of the potential thereafter remaining or thereafter applied to said external electrodes.

7. The combination of a gas-filled tube having two hard metallic internal electrodes and two external electrodes which are spaced and insulated from each other, a work circuit connected between the internal electrodes of the tube which includes a source of potential the magnitude of which is less than the voltage required to break down the gas between the internal electrodes of the tube and greater than that required to sustain ionization between said internal electrodes of the tube after ionization has started, means for applying a potential between the external electrodes for initiating gaseous ionization within the tube, and means independent of the circuit of the external electrodes for deionizing the gas within the tube after the voltage applied between the external electrodes has been removed.

8. The combination of a gas-filled tube having a plurality of hard substantially equal metallic internal electrodes and two external electrodes, a source of potential the magnitude of which is less than the potential required to initiate ionization of the gas within the tube, a load interconnected between the source of potential and two of the internal electrodes of the tube, and means for applying a potential between the external electrodes for initiating gaseous ionization within the tube and for operating the load uninfluenced by transient variations in the magnitude, polarity or phase of the potential thereafter remaining or thereafter applied to said external electrodes.

9. The combination of a gas-filled tube enclosing a plurality of solid metallic electrodes spaced from each other, a plurality of electrodes mounted external of the envelope of the tube which are not connected to the internal electrodes, and means for applying a potential to the external electrodes to produce gaseous ionization between the internal electrodes of the tube.

10. The combination of a gas-filled tube enclosing a plurality of unheated metallic electrodes spaced from each other, a plurality of external electrodes for the tube which are not connected to the internal electrodes, and means for applying a potential to the external electrodes for initiating ionization of the gas within the tube between its internal electrodes.

11. The combination of a gas-filled tube enclosing a plurality of solid unheated metallic electrodes spaced from each other and having a plurality of external electrodes not connected to the internal electrodes, a source of potential connected to the internal electrodes the magnitude of which is insufficient to break down the gap between the internal electrodes but is greater than that required to maintain gaseous ionization within the tube after it is started, and means for applying a potential to the external electrodes for initiating gaseous ionization within the tube.

LELAND KASSON SWART.